JOURNAL
OF THE
WASHINGTON ACADEMY OF SCIENCES

VOL. 46 NOVEMBER 1956 No. 11

MATHEMATICS.—*Unimodular matrices of order 2 that commute.*[1]

KARL GOLDBERG, National Bureau of Standards. (Communicated by C. H. Page.)

(Received September 12, 1956)

We shall prove the following:

Theorem: Let A and B be rational integral unimodular matrices of order 2. Then A and B commute if and only if they are, within sign, powers of the same rational integral unimodular matrix.

A consequence of this theorem is: *Every abelian subgroup of the modular group is cyclic.*

The sufficiency is clear.

For the necessity it will be sufficient to find any matrix K such that $A = e_1K^m$ and $B = e_2K^n$ with m and n rational integers and $e_i = \pm 1$ for $i = 1, 2$. Let $(m, n) = s$, $m_0 = m/s$, $n_0 = n/s$ and $K_0 = K^s$. Then there exist rational integers a and b such that $am + bn = s$ so that

$$K_0 = K^s = K^{am+bn} = e_1^a e_2^b A^a B^b$$

is a rational integral unimodular matrix with the property that

$$A = e_1 K_0^{m_0} \quad \text{and} \quad B = e_2 K_0^{n_0}.$$

If A is scalar then $A = \pm B^0$, which satisfies the theorem trivially. In what follows we shall assume that A is nonscalar.

Since A is of order two and not scalar it is non-derogatory. Thus $AB = BA$ implies, see [1], that B is a polynomial in A, or that there exists numbers σ and ρ such that $B = \sigma A + \rho I$, where I is the identity matrix of order 2. If A is diagonal then B is diagonal and the fact that it is unimodular and not scalar implies $\sigma = \pm 1$ and $\rho = 0$. If A is not diagonal then we can compare off diagonal elements, to show that σ, and therefore ρ, must be rational, see [2]. It follows that there must be integers x, y and z relatively prime in pairs with $xz \neq 0$ such that

$$zB = xA + yI. \tag{1}$$

If we denote the characteristic roots of A by α_1 and α_2 and those of B by β_1 and β_2 we have

$$z\beta_i = x\alpha_i + y \qquad i = 1, 2. \tag{2}$$

From this equation we see that if the characteristic roots of A are irrational they lie in the same quadratic field as those of B. We shall treat this case first.

Since the characteristic roots of A are irrational they are distinct. Therefore there exists a non-singular matrix U such that

$$UAU^{-1} = \begin{pmatrix} \alpha_1 & 0 \\ 0 & \alpha_2 \end{pmatrix}.$$

Since A is unimodular α_1 is a unit in a quadratic field and so is, within sign, a power of μ the fundamental unit of that field if it is real or the primitive root of unity of highest period if it is complex. That is, for some rational integers m and $e_1 = \pm 1$ we have

$$\alpha_1 = e_1\mu^m \quad \text{and} \quad \alpha_2 = e_1\bar{\mu}^m$$

where $\bar{\mu}$ denotes the conjugate of μ.

We can rewrite this in matrix form by letting

$$\Lambda = \begin{pmatrix} \mu & 0 \\ 0 & \bar{\mu} \end{pmatrix}$$

to obtain $UAU^{-1} = e_1 \cdot \Lambda^m$ or

$$A = e_1(U^{-1}\Lambda U)^m.$$

[1] This work was supported in part by the Office of Naval Research.

Now if UAU^{-1} is diagonal so is UBU^{-1} as can be seen from equation (1). And because the characteristic roots of B are units in the same quadratic field as those of A there must be rational integers n and $e_2 = \pm 1$ such that $UBU^{-1} = e_2\Lambda^n$ or

$$B = e_2(U^{-1}\Lambda U)^m,$$

which completes the proof for the case of irrational characteristic roots.

If the characteristic roots of A are rational we have either

$$\alpha_1 = -\alpha_2 = \pm 1 \quad \text{or} \quad \alpha_1 = \alpha_2 = e_1 = \pm 1.$$

In the case of distinct rational roots, equation (2) and the fact that B is unimodular yields $x^2 = z^2 = 1$ and $y = 0$ or $A = \pm B$ which satisfies the theorem trivially.

In the case of equal roots there exists a non-singular matrix U such that

$$UAU^{-1} = e_1\begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix} \qquad e_1 = \pm 1$$

From equations (1) and (2) it is clear that

$$UBU^{-1} = e_2\begin{pmatrix} 1 & r \\ 0 & 1 \end{pmatrix} \qquad e_2 = \pm 1, r = e_1e_2xz^{-1}$$

Let

$$K = U^{-1}\begin{pmatrix} 1 & z^{-1} \\ 0 & 1 \end{pmatrix}U.$$

Then

$$A = e_1K^z$$

and

$$B = e_2K^{e_1e_2x}$$

Since z and e_1e_2x are rational integers, this completes our proof.

REFERENCES

(1) MAC DUFFEE, C. C. *The theory of matrices*: 93-94. New York, 1946.

(2) TAUSSKY-TODD, O. *On matrix classes corresponding to an ideal and its inverse Lemma 1.* To appear in Illinois Journ. Math.

SURGE VOLTAGE BREAKDOWN IN A NONUNIFORM FIELD

A knowledge of high-voltage discharge phenomena is of primary importance in the design of electrical equipment. For example, an understanding of electrical breakdown in air makes possible accurate determination of safe and economic insulation requirements for high-voltage transformers and other apparatus. Information on discharge mechanisms is also of considerable value in electrical surge measurements carried out to provide data for the design of power systems.

Although several acceptable theories of breakdown in a uniform field have been developed,[1] the much more common problem of nonuniform field breakdown has been relatively unexplored. To provide data on this process, an investigation was recently conducted by J. H. Park and H. N. Cones, of the National Bureau of Standards.[2] Their results verify a difference, suggested by the data of earlier experimenters, between breakdown mechanisms in uniform and nonuniform fields.

Cathode-ray oscilloscope records and photographs of the discharges obtained by the Bureau reveal that in a nonuniform field discharge streamers (corona) are initiated by a sudden current rise (the first discharge pip). This current quickly decreases, remaining near zero unless complete breakdown is to occur. For gap lengths sufficiently short or for voltages sufficiently high, the first discharge pip is followed by a second rise in current which increases until breakdown occurs. Polarity also affects the gap spacing at which breakdown or discharge streamers occur and the speed of formation of these streamers.

The tests were conducted under usual laboratory conditions of pressure and humidity, and the nonuniform field was obtained by using electrodes of dissimilar geometry. The high-voltage electrode consisted of a circular plane,

[1] *Basic process of gaseous electronics*, by L. B. LOEB, chapters 8 and 9 (Univ. of California Press, 1955); *Theory of gaseous conduction and electronics*, by F. A. MAXFIELD and R. R. BENEDICT, page 270 (McGraw-Hill, 1941); and *The mechanism of the electric spark*, by L. B. LOEB and J. M. MEEK (Stanford University Press, 1941).

[2] For further technical details, see *Surge voltage breakdown of air in a nonuniform field*, by J. H. PARK and H. N. CONES, Journ. Res. NBS 56: 201. April 1956.

84 cm in diameter, made of an aluminum alloy. It was placed 86.4 cm above and parallel to the laboratory floor, which had a grounded metal grid imbedded in its surface and was used as a ground plane. The ground electrode was a sphere, 1.6 cm in diameter, mounted at the end of a conductor and located an adjustable distance beneath the center of the high-voltage plane electrode. The conductor, centered in a grounded tube, was connected to a coaxial cable, which terminated at a cathode ray oscillograph. This arrangement permitted an accurate measurement of prebreakdown current and computation of the initial electrical field.

Discharge phenomena were studied by holding the peak voltage of the applied surge at 145 kv and changing the gap spacing. Data were obtained under four conditions of applied voltage: a steeply rising surge with the sphere positive, a slowly rising surge with the sphere positive, a steeply rising surge with the sphere negative, a slowly rising surge with the sphere negative. For gap spacings less than 28 cm when the sphere is positive or 15 cm when the sphere is negative, complete breakdown between sphere and plane usually takes place.

The first discharge pip appeared at gap spacings up to 56 cm for a positive sphere and 46 cm for a negative sphere, but at these large spacings time delays were erratic. At gap spacings less than 46 cm with the sphere positive and 30 cm with the sphere negative a discharge generally appeared with little time lag—less than 0.1 μsec for a steeply rising surge and less than 1 μsec for a slowly rising surge.

In a case where breakdown would ordinarily occur, chopping the voltage after the first discharge rise prevented breakdown. The initial streamer patterns that formed when the voltage was chopped were similar in appearance to those obtained when there was no second discharge rise. In calculating the propagation velocity of the streamers, their length was determined from photographs, and their time of formation was taken as the interval between the start of the first discharge pip and the chopping. The mean streamer propagation velocity is 500 cm/μsec for sphere negative and 800 cm/μsec for sphere positive.

An analysis of streamer formation and channel development provides a more complete explanation of the mechanism leading to breakdown. Streamer photographs show where regions of high charge density have travelled from the sphere to the plane along the lines of force of the applied field. When the sphere is positive, a negative ion situated in the high-field region near the sphere can supply a free electron, which in ionizing neutral molecules forms an electron avalanche. The ionization or recombination process furnishes photons which liberate electrons in the nearby field. These electrons are attracted to the sphere, leaving regions of high positive space charge density near the surface of the sphere. The photo electrons liberated in the volume immediately ahead of the charged region are attracted to it so that the positive region moves from the sphere to the plate, creating a positive streamer.

If the initial streamer pattern produces a sufficiently high gradient, a channel starts to develop at the rate of 3 cm/μsec. As this channel forms, it serves as a good conductor from its origin at the sphere to its leading end. Breakdown takes place along a zigzag channel that has completely spanned the gap.

When the sphere is negative, the electron avalanches formed in the region near the sphere travel towards the plate, where they initiate positive streamers from the plate to the sphere. Electrons are then released from the sphere by high-energy photons impinging on it, positive ion bombardment, or field emission. Negative streamers are formed in much the same way as the positive ones, but in this case electrons repelled from the sphere cause a negative region to move toward the plate. A streamer formed when the sphere is positive has a higher velocity of propagation than a negative streamer because electrons move in the direction of the increasing gradient so that the electron avalanches develop faster. The positive streamer can be initiated over a longer gap than the negative streamer because avalanches can form positive streamers for lower applied gradients near the sphere when the sphere is positive.

For the negative sphere, a conducting channel starts out perpendicular to the plane but after a short distance changes its course and makes a zigzag path to the sphere. These channels either contact the sphere or connect with a channel development from the sphere. For shorter gap spacing or considerable overvoltage, breakdown occurs when an initial streamer develops into a conducting channel. The breakdown path is then less zigzag, seeming to follow a line of force.

PALEONTOLOGY.—Chiloguembelina, *a new Tertiary genus of the Heterohelicidae (Foraminifera)*.

ALFRED R. LOEBLICH, JR., and HELEN TAPPAN, U. S. National Museum.

(Received October 1, 1956)

Recent studies of planktonic Foraminifera by the writers have shown that some early Tertiary species previously referred to *Guembelina* Egger have characters not in keeping with that genus. As these species have both morphological distinctions and a differing geologic range, they are here considered to be distinctive and made the basis of a new generic name, *Chiloguembelina*.

Family HETEROHELICIDAE Cushman, 1927

Chiloguembelina Loeblich and Tappan, n. gen.

Type species.—*Guembelina midwayensis* Cushman, 1940.

Derivation.—*Chilo*, from *cheilos* Gr. n. lip, rim + *Guembelina*, genus of Foraminifera. Gender feminine.

Test free, flaring; inflated chambers biserially arranged, with a tendency to become somewhat twisted; sutures distinct, depressed; wall calcareous, finely perforate, radial in structure, surface smooth to hispid; aperture a broad low arch bordered with a produced necklike extension of the chamber, commonly this forms a more strongly developed flap at one side, so that the aperture appears to be directed toward one of the flat sides of the test.

Remarks.—*Chiloguembelina* differs from *Guembelina* Egger in the presence of the apertural necklike extension from the final chamber, in the tendency to develop a twisted test and an asymmetrical aperture, directed toward the flat side instead of the edge of the test. Unlike true *Guembelina*, it does not have an early coiled portion in the microspheric generation, all specimens being wholly biserial throughout.

Chiloguembelina is found only in post-Cretaceous strata, in the Paleocene and Eocene. In addition to the type species, *Guembelina crinita* Glaessner, *G. cubensis* var. *heterostoma* Bermudez, *G. mauriciana* Howe and Roberts, *G. trinitatensis* Cushman and Renz, *G. venezuelana* Nuttall, and *G. goodwini* Cushman also should be placed in *Chiloguembelina*.

Chiloguembelina midwayensis (Cushman)

Gümbelina midwayensis Cushman, Contr. Cushman Lab. Foram. Res. **16:** p. 65, pl. 11, fig. 15. 1940.

Gümbelina morsei Kline, Mississippi Geol. Survey Bull. 53, p. 44, pl. 7, fig. 12. 1943.

Test free, small, flaring; the 4 to 6 pairs of inflated to subglobular and rapidly enlarging chambers biserially arranged but slightly twisted; sutures distinct, depressed, nearly straight and slightly oblique; wall calcareous, finely perforate, surface smooth to finely spinose especially in the terminal portion of the test; aperture a broad low arch with a bordering necklike extension of the chamber, commonly forming a more strongly developed flap at one side, so that the aperture appears to be directed toward one of the flat sides of the test instead of toward its edge.

Remarks.—This species shows considerable variation in the degree of flaring of the test and in the development of the apertural lip. Some specimens may show a nearly symmetrical lip, others show a less well preserved lip so that it appears to consist of lateral flanges and in some slightly twisted tests the aperture may appear to be directed to one side, with a stronger development of the lip at one side than on the other. All gradations may be found, proving these to be merely individual variations.

Types and occurrence.—Holotype (Cushman Coll. no. 35715) from the Midway group, on U. S. Highway 80, south of Sucarnochee Creek, ½ mile southwest of Livingston, Sumter County, Ala. The writers have also observed this species in Midway strata of Texas and Alabama, the Brightseat formation of Maryland, and in the Hornerstown formation of New Jersey.

PALEONTOLOGY.—Galaxaura (*calcareous algae*) *and similar fossil genera.*

GRAHAM F. ELLIOTT, Iraq Petroleum Co., Ltd. (Communicated by Alfred R. Loeblich, Jr.).

(Received August 22, 1956)

In northern Iraq parts of the Lower Cretaceous succession are characterized by the occurrence of frequent but fragmentary calcareous algae (Elliott, 1955b). At a level dated as Barremian-Aptian the foraminifer *Orbitolina* is accompanied by *Munieria baconica* Deecke and a second fragmentary alga which during routine studies was known by a code number, for while it was recognizable, a reconstruction was not possible. Exceptional material later revealed that these fragments are of a species surprisingly similar to forms from the Permian of the same area and elsewhere. This new species is now described and its significance discussed. I am indebted to the Iraq Petroleum Co., Ltd., London, for permission to publish this note.

Genus **Permocalculus** Elliott, 1955

Permocalculus inopinatus, n. sp.

Description.—Thallus fingerlike, somewhat irregular, circular in cross section, up to 5 mm long and 1.75 mm in transverse diameter; calcification varying between different individuals from a thin irregular peripheral development to a nearly solid thallus; sporangia ill-defined, subcortical in position; pores with diameter of 0.020 mm at the outer edge of the calcification where they are clearly visible, only occasionally seen extending inwards, when they are fine and twisted, widening at the surface.

Syntypes.—The specimens illustrated in Figs. 1A, B, from the Aptian limestone of Ru Kuchuk, Chama, Mosul Liwa, N. Iraq, Geol. Coll. Iraq Petroleum Co., Ltd., London, reg. nos. DM. 1286, 1284.

Other material.—Numerous random sections, mostly fragmentary, from the Barremian-Aptian limestones of Ru Kuchuk and Jabal Gara, Mosul Liwa; Sarmord, Sulemania Liwa; Koi Sanjak, Erbil Liwa; all in northern Iraq. Also from a similar horizon at Wady Hajar, Hadhramaut, southern Arabia.

This species bears a surprising resemblance to species of *Permocalculus* from the Permian of the same area (Elliott, 1955a) and elsewhere, notably *P. solidus* (Pia) and *P. digitatus* Elliott. It is evidently the calcified thallus of a very similar plant, though it can readily be distinguished by the very different associated algal and other species.

The Permian *Gymnocodium*, after several changes in classification, was compared by Pia to the Recent *Galaxaura* and placed with it in the Chaetangiaceae. The writer (Elliott, 1955a) confirmed this resemblance after an examination of the calcareous micro-structure of the Recent *Galaxaura fastigiata* Decaisne and the Permian *Gymnocodium bellerophontis* (Rothpletz), in which the calcification is subdermal only, and separated off various Permian species, differing in form and calcification, as *Permocalculus*. A similar comparison could have been made between the Recent *Galaxaura glabriuscula* Kjellmann and *Permocalculus solidus* (Pia): in the Recent species there is marked calcification, particularly of the stem, which is not well differentiated from the other portions of the thallus.

In view of the close general similarities between *Galaxaura* and the fossil forms the additional evidence available from the former should be considered in classifying the latter; the recent study of Svedelius (1953) is of particular interest since this writer, unlike many botanists, attaches some degree of taxonomic importance to calcification. *Galaxaura* is represented by sexual and nonsexual generations; the plants of the two are different, and the former is itself represented by male and female plants, with differently sized cavities for reproductive structures. In spite of the frequent association of plants of two generations, and close examination for structural peculiarities held in common, however, Svedelius concludes that only by experimental sporeculture can the plants be conclusively paired as representing different generations of the same species.

If this difficulty arises with living plants, it seems impossible with the fossils, where the calcification alone remains, to classify them on other than a strictly morphological basis, as was done by the writer in separating *Permocalculus* from *Gymnocodium*, placed together in the Gymnocodiaceae as a comparable family to the

Chaetangiaceae. So long as the former was represented by Permian species only, the distinction was clear-cut and suggested that similar algae had twice independently achieved calcification. The known Cretaceous forms are therefore of especial interest.

Corallinites galaxaura Massalongo, from the Italian Lower Cretaceous, is known only from this writer's early account and figures (1856) which show a small segmented alga, and while possibly a *Galaxaura* (see also Massalongo, 1859) nothing more can be said of it.

Permocalculus inopinatus, described above from the Lower Cretaceous of the Middle East, is extremely similar to certain Permian species.

Gymnocodium nummuliticum Pfender was described from the Egyptian Eocene and recorded also from the Upper Cretaceous of France and Spain (Pfender, 1940). This alga was described as very similar to the Permian *G. bellerophontis* (Rothpletz): the figures of Cuvillier (1930) quoted by Pfender are too small to be useful for a detailed study, and the present writer (1955a), without actual specimens for examination, did not consider them further. In material from Wady Hajar, Hadhramaut, southern Arabia, however, in a Lower Cretaceous *Orbitolina*-limestone of probable Barremian age, abundant debris of *Permocalculus inopinatus* was accompanied by at least one section similar to the Permian *Gymnocodium bellerophontis*, just as described by Pfender.

It would seem, therefore, that algae ancestral to the present-day Chaetangiaceae have existed since the Permian, though represented in varying abundance at different horizons. Their classification, in view of the difficulties attaching to that of the living plants, is best made, in the present state of knowledge, on a strictly morphological basis.

REFERENCES

CUVILLIER, J. *Revision du Nummulitique Égyptien*. Mém. Inst. Égypt. **16:** ref. pl. 8. 1930.

ELLIOTT, G. F. *The Permian calcareous alga* Gymnocodium. Micropaleontology **1** (1): 83–90. 1955a.

———. *Fossil calcareous algae from the Middle East*. Micropaleontology **1** (2): 125–131. 1955b.

MASSALONGO, A. *Studii paleontologici*: ref. p. 42. Verona, 1856.

FIG. 1.—*Permocalculus inopinatus*, n sp.: A, Longitudinal section; B, transverse section × 30: syntypes. Lower Cretaceous (Aptian); Ru Kuchuk, Chama, Mosul Liwa, Iraq.

MASSALONGO, A., and SCARABELLI, G. *Studii sulla flora fossile e geologia stratigraphica del Senigalliese:* ref. p. 92 (footnote). Imola, 1859.

PFENDER, J. *Les algues du nummulitique Égyptien et des terrains Crétacés-Éocènes de quelques régiones mésogéenes.* Bull. Inst. Egypt. **22:** 225–250. 1940.

SVEDELIUS, N. *Critical studies on some species of* Galaxaura *from Hawaii.* Nov. Act. R. Soc. Sci. Upsala (4) **15** (9): 1–92. 1953.

H. M. S. "LOO"

The insigne of England's Tudor and Stuart kings, the crowned rose, has provided a clue that enabled a Smithsonian historian to reconstruct a two-century-old tragedy of the Spanish Main—the shipwreck of a British man-of-war and the desperate plight of 280 sailors on a desert island beset by hostile savages.

Off the central Florida keys, about 35 miles southwest of the town of Marathon, is a submerged reef—marked "Looe reef" on maritime charts. Near it the sea bottom is strewn with metal objects, long since covered with a sand crust that makes them the same color as the bottom and nearly indistinguishable. They obviously are the remains of some shipwreck. The wreck was first explored by a party consisting of Bill Thompson, of Marathon, Fla.; Dr. and Mrs. George Crile, Jr., of Cleveland, Ohio; Mr. and Mrs. E. A. Link, of Binghamton, N. Y.; Mr. and Mrs. James Rand, of Cleveland, Ohio; Mr. and Mrs. John Shaheen, of New York City; and Arthur McKee, of Homestead, Fla. The party was accompanied by Mendel L. Peterson, Smithsonian Institution curator of naval history. Largely through Mr. Peterson's researches the ship now has been identified and its complete story recovered. It was H. M. S. *Loo*, a frigate of 40 to 44 guns, under Capt. Ashby Utting, lost off the keys after running aground in the midwinter of 1744.

The metal objects recovered went part of the way in reconstructing the story. They were cannonballs, nails, fragments of rum and brandy bottles, the knob of a walking stick, some fragments of table plates decorated with a blue flower design, a 2,000-pound cannon barrel, and various 18th-century European coins. Cast into the barrel was the "crowned rose." It was an insigne used by both the Stuart and Tudor kings. As its use was discontinued after Queen Anne, the date of the shipwreck must have been before, or shortly after, her death. The normal life of an iron barrel on shipboard, it was ascertained, was probably not more than 40 years. If it is assumed that the cannon had been put in service in the last year of Anne's reign, 1714, the wreck could not have been later than 1754. Other evidence indicated that it could not have been earlier than the start of her reign.

Thus Peterson got the clue by which he was able to search records of the British Admiralty over a specific period, and bit by bit—from orders, letters, payrolls, and other papers—emerged the story of the wreck of the *Loo*. Looe is a town in Cornwall from which the ship took its name. How the Florida reef happened to have that name nobody knew. Here in brief is the story of the frigate as traced from the clue of the crowned rose, which has recently been published by the Smithsonian Institution where many of the articles recovered from the wreck now are being studied:

The *Loo* had sailed from Cuba with a small prize ship. During the night she ran close to the reef, while off her assumed course, and "three or four severe seas crushed the ship against the reef and she began sinking rapidly. The reef was then above water, a small desert island. Captain Utting, however, was able to land safely all his own crew and that of the captured prize ship.

"The desperate situation of the group was evident to all. "Here were 280 men stranded on a small sandy islet just off a hostile coast swarming with the savage Caloosa Indians who murdered Englishmen on sight. To add to the insecurity was the evident fact that in a blow of any force the whole islet would be swept by waves. At night Utting posted watches, each consisting of 25 marines and 25 sailors at the water's edge as 'centenells' to prevent a surprise night attack. Meanwhile the men, frightened and confused, became very rebellious and mutinous, dividing into parties and claiming that the officers no longer had any authority over them. They clamored to leave the island immediately. Utting took no notice of them, but, with the few men who would work, continued efforts to recover water and other provisions from the wreck."

Two days later the captain was able to get off all the men in small boats and eventually steered northward toward the harbor of Port Royal, S. C. This was a direction in which he did not want to go but proceeded "rather than all be drowned." But everybody came through alive. Once his crew were safe Utting's first chore was to find a colonial justice of the peace and make depositions in connection with a court martial for loss of his ship, which he knew was inevitable. From the Admiralty records Peterson obtained a full account of this court martial, at which the captain was acquitted of all charges.

BACTERIOLOGY.—*Quantitative studies of differential staining reactions, III: A quantitative acid-fast stain*[1]. A. F. WOODHOUR, Catholic University of America. (Communicated by E. R. Kennedy).

Bacteria in the genus *Mycobacterium* are resistant to staining with basic dyes, but once stained the cells are resistant to decolorization with acid-alcohol. This procedure is known as the acid-fast reaction, and possession of the acid-fast property is the chief characteristic that differentiates this genus from other Schizomycetes.

Attempts have been made to associate the virulence of mycobacteria with some consistent aspect of the organisms. Middlebrooke, Dubos, and Pierce (1947) found that virulent tubercle bacilli form microscopically demonstrable serpentine cords which enable the organisms to spread more readily on the surface of liquid and solid media. Avirulent forms do not form such cords. These investigators also reported that the virulent bacilli are strongly acid-fast, whereas the avirulent forms are much less acid-fast. It should be possible, in the light of this information, to associate virulence with a quantitative determination of acid-fastness.

Until the present time no quantitative method has been described to estimate the degree of acid-fastness among species or strains of *Mycobacterium*. Kennedy and Barbaro (1953) reported an accurate quantitative method for determining the adsorption of crystal violet by bacteria based on micro-Kjeldahl analyses of bacterial cells and stain reagents. The present report describes a modification of this procedure as applied to the acid-fast reaction and presents evidence for the existence of degrees of acid-fastness among the mycobacteria.

MATERIALS AND METHODS

The crystal violet used throughout the investigation has been described previously (Kennedy and Barbaro, 1953).

Basic fuchsin was obtained from the National Aniline & Chemical Co., Inc., New York, N. Y. (total dye content, 95 percent, Certification no. NF 57, C. I. no. 677).

Modified Ziehl-Neelsen carbol fuchsin was prepared by dissolving 3.15 g of basic fuchsin in 10 ml of 95 percent ethyl alcohol; a solution composed of 2 g of phenol in 95 ml of deionized water was added to the alcoholic dye solution.

The crystal violet solution, decolorizing agent (3 percent hydrochloric acid-alcohol) and M/15 phosphate buffer were stored at 5 C and maintained as close as possible to that temperature throughout the procedure. The modified Ziehl-Neelsen carbol fuchsin was stored at room temperature to avoid excessive precipitation of carbolic acid.

The organisms were obtained from cultures maintained in this laboratory and the American Type Culture Collection and maintained at room temperature. The acid-fast organisms used in the study were:

	Strain No.
Mycobacterium tuberculosis var. *hominis* ATCC no. 9360	H37Rv
Mycobacterium tuberculosis var. *hominis* ATCC no. 9431	H37Ra
Mycobacterium tuberculosis var. *bovis* ATCC no. 9834	549

The non-acid-fast organism was:

Corynebacterium xerose	513

The tubercle bacilli were cultivated at 37 C for 3 weeks on Dubos broth base to which "Dubos medium albumin" and 1.2 percent agar had been added. All other organisms were cultivated at 37 C for 24 to 72 hours on a modified tryptose agar medium.

The preparation of cell suspensions and micro-Kjeldahl procedure have been described previously (Kennedy and Barbaro, 1953).

EXPERIMENTAL PROCEDURE AND RESULTS

The procedure for a typical quantitative acid-fast reaction was as follows: Organisms

[1] This work was supported in part by funds received from the American Association for the Advancement of Science on the recommendation of the Washington Academy of Sciences.

TABLE 1.—QUANTITATIVE ACID-FAST REACTION AS DETERMINED BY MICRO-KJELDAHL ANALYSES OF CRYSTAL VIOLET AND BACTERIA

SPECIES	ANALYSES ON SUPERNATANTS			ANALYSES ON BACTERIA			PER MG BACTERIAL N	
	Original dye N	Dye N after staining (unadsorbed)	Dye N adsorbed	Acid-fast stained bacteria	Unstained bacterial N	Dye N retained	Dye N adsorbed	Dye N retained
	mg	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*
Myco. tuberculosis var. *hominis* H37Rv	0.40	0.22	0.18	0.73	0.69	0.04	0.26	0.06
Myco. tuberculosis var. *hominis* H37Ra	0.40	0.10	0.30	1.12	1.10	0.02	0.27	0.02
Myco. tuberculosis var. *bovis*	0.37	0.03	0.34	1.46	1.39	0.07	0.25	0.05
Myco. phlei	0.42	0.04	0.38	1.73	1.69	0.04	0.23	0.03
C. xerose	0.41	0.06	0.35	2.21	2.21	0.00	0.11	0.00

to be tested were harvested in 0.85 percent saline solution, heat-killed at 99 C for 30 minutes, and washed until the supernatant fluid was nitrogen free as determined by micro-Kjeldahl analyses. The washed cell suspension was diluted to contain the desired concentration of bacteria per milliliter. One ml of the uniformly mixed bacterial suspension was added in triplicate to thick-walled centrifuge tubes and centrifuged in the cold (0–5 C) at approximately 8,000 rpm (rcf 6,000) for 30 minutes. The supernatant fluid was discarded, and 2 ml of suitably diluted crystal violet stock solution were added to the packed cells. After thorough mixing, the tubes were stoppered and kept at room temperature overnight (approximately 18 hours). The next day the stoppers were removed and the tubes centrifuged in the cold for 30 minutes. The supernatant crystal violet solution was transferred to a Kjeldahl flask, and the packed cells were washed with 2 ml of buffer solution at pH 7.1 and centrifuged again in the cold. The buffer washings were transferred to the Kjeldahl flask and one ml of 3 percent hydrochloric acid-alcohol was added to the packed cells. The cells were mixed thoroughly and immediately centrifuged in the cold for 5 minutes. The supernatant acid-alcohol and subsequent buffer wash were placed in a second Kjeldahl flask for analysis. The packed cells were suspended in buffer solution and transferred quantitatively to a third Kjeldahl flask for analysis.

Unstained bacterial suspensions and dye solutions were added directly to Kjeldahl flasks in triplicate and analyzed. These values were used as control determinations.

Table 1 contains representative data obtained when this procedure was applied to acid-fast and non-acid-fast organisms. In all cases each figure indicates the average of triplicate determinations. The method is such that each of the triplicates agrees within 0.02 mg of nitrogen. To simplify the comparison of results, the values in the last two columns have been calculated on the basis of one mg of bacterial nitrogen. The term *adsorption* is used to describe the dye originally taken up by the bacterial cells; the term *retention* means the amount of dye which remains in the cells after decolorization. The adsorption values are similar among all acid-fast organisms tested but the retention values differ. The difference in retention indicates degrees of acid-fastness.

One ml of modified Ziehl-Neelsen carbol fuchsin was employed in place of crystal violet in the above procedure under the same conditions. Table 2 contains representative data obtained with this procedure. One of the most significant differences between this modification and the crystal violet procedure is the generally higher adsorption values obtained with carbol fuchsin, though the retention values are similar. The individual retention values are significant: the two supposedly most acid-fast organisms of the group retain the most dye while the least acid-fast organisms retain appreciably less dye.

DISCUSSION

The application of a quantitative technique to the acid-fast reaction is dependent to a great extent on the preparation of homogeneous bacterial suspensions and adequate control of the decolorization procedure. The difficulty of preparing homogeneous suspensions of mycobacteria can be overcome by the use of Tween 80-albumin medium which has been recommended for the cultivation of tubercle bacilli. The formation of cords in virulent species is inhibited on this medium (Middlebrooke, Dubos, Pierce, 1947). Numerous thorough mixings and centrifugations of the cells with subsequent double filtration through cotton results in homogeneous suspensions. This is substantiated by analyses of triplicate samples of unstained organisms. The results agree within the limits of error of the micro-Kjeldahl method ±0.02 mg nitrogen. The utilization of low temperature centrifugation during the decolorization process is believed to slow the decolorization process sufficiently to allow complete removal of measureable dye from non-acid-fast organisms without over decolorization of the weakly acid-fast *Myco. phlei*.

The use of crystal violet in the procedure described here is supported by the work of Benians (1912–1913) who found that, when crystal violet was employed without a mordant in the acid-fast reaction, acid-fast organisms retain dye after acid-alcohol decolorization while non-acid-fast organisms are completely decolorized. In the course of the present work, crystal violet was found much easier to use than carbol fuchsin. When triplicate samples of the respective dyes were subjected to analyses, crystal violet samples always agreed within the limits of error of the procedure while carbol fuchsin replicates showed marked discrepancies on many occasions. In addition, carbol fuchsin takes much longer to digest in Kjeldahl analysis than does crystal violet and therefore lengthens the complete procedure. The results in the tables, however, represent experiments in which triplicate dye samples agreed within the limits of error of the method.

There appear to be many variables that influence the values obtained, such as composition of media, dye concentration, staining time, temperature of staining and decolorizing procedures. These factors undoubtedly influence the acid-fast reaction when performed on glass slides. The values found (tables 1 and 2) are relative rather than absolute but it should be remembered that they are the result of triplicate analyses and agree within 0.02 mg nitrogen. The reliability of these values is further emphasized by the fact that analyses were made of the supernatant fluids as well as stained cells and it is possible to account for all dye, adsorbed and unadsorbed, used throughout the procedure.

In the interpretation of quantitative acid-fast values consideration must be given to the physiological condition of the cells used. Dubos and Davis (1946) pointed out the heterogeneity of fully grown cultures of tubercle bacilli. The cells in a given culture vary greatly in age and therefore, physiological state. In addition, when organisms

TABLE 2.—QUANTITATIVE ACID-FAST REACTION AS DETERMINED BY MICRO-KJELDAHL ANALYSES OF CARBOL FUCHSIN AND BACTERIA

SPECIES	ANALYSES ON SUPERNATANTS			ANALYSES ON BACTERIA			PER MG BACTERIAL N	
	Original dye N	Dye N after staining (unadsorbed)	Dye N adsorbed	Acid-fast stained bacteria	Unstained bacterial N	Dye N retained	Dye N adsorbed	Dye N retained
	mg	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*	*mg*
Myco. tuberculosis var. *hominis* H37Rv	0.58	0.24	0.34	1.04	0.97	0.07	0.35	0.07
Myco. tuberculosis var. *hominis* H37Ra	0.61	0.27	0.34	0.91	0.90	0.01	0.37	0.01
Myco. tuberculosis var. *bovis*	0.60	0.13	0.47	1.50	1.43	0.07	0.33	0.05
Myco. phlei	0.61	0.18	0.43	1.72	1.69	0.03	0.25	0.02

grow in clumps the environmental conditions of cells at the periphery are different from those of cells at the center. These conditions might well reflect differences in structure and metabolism. Since conditions of cultivation are kept constant for all organisms it seems justifiable to assume that these values are correct when applied to a culture as a whole. Possibly the values would be higher if only young organisms were used or considerably lower if only old organisms were used. Since, however, a mixture of both were employed the values indicate an average acid-fast value. The conditions are the same for all species to which the procedure has been applied.

With the classic acid-fast test performed on glass slides, visual observation does not necessitate the presence of abundant amounts of dye within the cells. The quantitative procedure, however, demands the presence of significant amounts of dye. The micro-Kjeldahl method measures 0.02 mg of nitrogen but when small amounts of organisms were used, even though the cells were visibly stained, the retained dye nitrogen could not be measured. This can be overcome by increasing the number of organisms so more adsorbed dye can be measured and decreasing the decolorization time to the extent that non-acid-fast organisms give no retention values, though they are visibly stained. This procedure indicated the minute quantity of dye retained by acid-fast organisms when stained by the classic method on glass slides.

The amount of dye retained per mg of bacterial nitrogen is significantly different among species of mycobacteria. The conclusion that degrees of acid-fastness exist among the mycobacteria agrees with reports of other investigators (Lamanna and Mallette, 1953; Bergey *et al.*, 1948). These workers based their conclusions on qualitative interpretations utilizing the classic Ziehl-Neelsen technique of staining. The data presented in this report indicate the existence of quantitative degrees of acid-fastness among mycobacteria whether stained with carbol fuchsin or crystal violet when the results are calculated as retained dye per unit of bacterial nitrogen.

The method which has been reported offers the first quantitative experimental approach to basic studies on the mechanism of the acid-fast reaction and to studies of the effects of environment, staining time, temperature of staining, dye concentration, and decolorizing agents.

SUMMARY

A quantitative acid-fast reaction based on micro-Kjeldahl analyses of reagents and of cells decolorized at low temperature is described.

Quantitative evidence is presented to show that degrees of acid-fastness exist among mycobacteria.

REFERENCES

BENIANS, T. H. C. *Observations on the gram positive and acid-fast properties of bacteria.* Journ. Path. Bact. **17:** 199–211. 1912.

BERGEY, D. H., *et al. Manual of determinative bacteriology.*, 6th ed. Baltimore, 1948.

DUBOS, R. J., and DAVIS, B. D. *Factors affecting the growth of tubercle bacilli in liquid media.* Journ. Exp. Med. **83:** 409–423, 1946.

KENNEDY, E. R., and BARBARO, J. F. *Quantitative adsorption of crystal violet.* Journ. Bacteriol. **65:** 678–680. 1953.

LAMANNA, C., and MALLETTE, M. F. *Basic bacteriology.* Baltimore, 1953.

MIDDLEBROOKE, G., DUBOS, R. J., and PIERCE, CYNTHIA. *Virulence and morphological characteristics of mammalian tubercle bacilli.* Journ. Exp. Med. **86:** 175–184. 1947.

Though the mills of God grind slowly, yet they grind exceedingly small.—
LONGFELLOW.

ZOOLOGY.—*North American harpacticoid copepods: 3*, Paracamptus reductus, *n. sp., from Alaska.*

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(Received July 30, 1956)

The genus *Paracamptus* is among the few genera of fresh-water Canthocamptidae occurring in Europe and Asia that has not been reported from North America. It is of interest therefore to record its occurrence on this continent, as represented by a new species found in Alaskan collections. The harpacticoid copepods listed as occurring with the new *Paracamptus* also represent new records for North America. Reference has been made (M. S. Wilson, 1956) to their discovery in Alaska, but these are the first locality records to be published. The genus *Maraenobiotus* is likewise a Eurasian genus of the Canthocamptidae not before known from North America.

I am indebted to O. A. Mathisen, Fisheries Research Institute, University of Washington, and to Kenneth Andress, Spenard, Alaska, for the collections containing this new species.

Paracamptus reductus, n. sp.

Figs. 1–16

Specimens examined.—Type lot: 9 ♀ (2 ovigerous), 4 ♂. Margin of Lake Tikchik, Bristol Bay area of southwestern Alaska (about lat. 60°N., long. 159°W.); August 19, 1954; O. A. Mathisen. Occurring with *Moraria duthiei* T. and A. Scott and *Maraenobiotus insignipes* (Lilljeborg). Holotype ♀, U. S. National Museum no. 99416; allotype ♂, no. 99417.

1 ♀ (ovigerous). Margin of Paxson Lake, Richardson Highway, Alaska, (about lat. 63°N., long. 145°W.); June 28, 1951; K. Andress. Occurring with *Moraria duthiei* and *M. mrazeki* T. Scott.

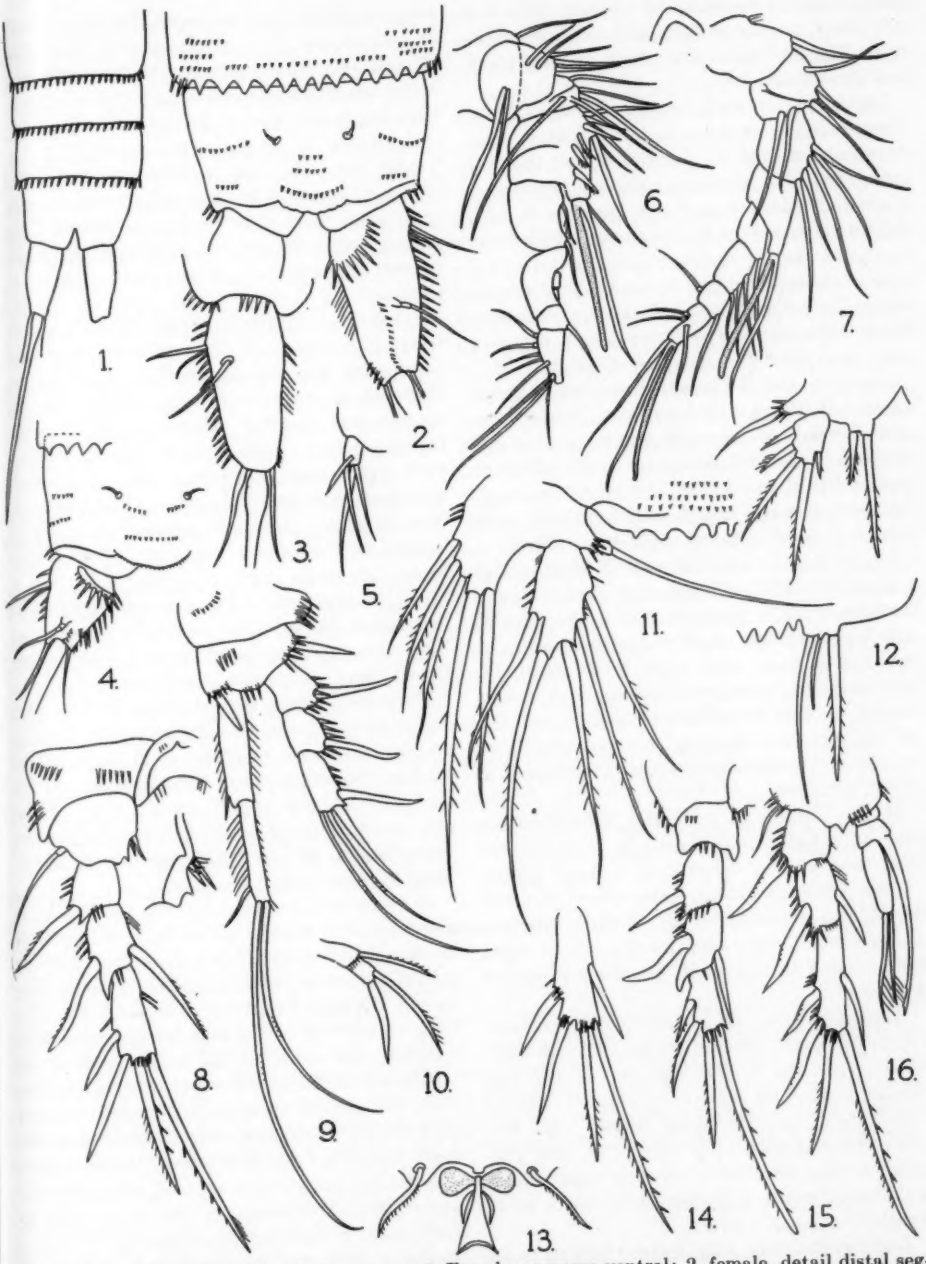
Diagnosis.—Caudal rami of female, length more than twice width; shorter in male; both sexes with curved crest of spinules near base of inner dorsal side and longitudinal crest of spinules posterior to insertion of dorsal seta. Leg 1 with three setae on endopod segment 2, both apical setae much longer than endopod and modified like those of exopod. Endopods lacking on legs 2–4 of female and on legs 2 and 4 of male; that of leg 3 normally developed in male, with two apical setae. Leg 5, segment 2 of both sexes, middle seta of similar stoutness and armature to other setae.

Description.—Length, dorsal midline, ♀ Tikchik Lake, 0.55–0.6 mm, Paxson Lake, 0.7 mm; ♂, 0.465–0.47 mm.

FEMALE: Posterior edge of all body segments, except the last, coarsely serrate on dorsal side (Fig. 2); surface covered by broken rows of minute spinules (partially indicated in Fig. 2). Ventrally, urosome segments not serrate but each with single unbroken row of spines (Fig. 1). Last segment with a few spines ventrally at bases of rami and a lateral group. Margin of anal operculum wavy or minutely spinulose.

Caudal ramus (Figs. 2, 3) constricted distally, length more than twice its greatest width (2.3–2.45 times); longer than outer margin of last body segment (about 1.4 times). Lateral setae placed as usual, the proximal on outer margin near base and accompanied by shorter seta; distal seta placed a little distad on ventral surface. Dorsal seta on a twice segmented base, placed just distad to middle of ramus. Entire outer margin including that above proximal seta, armed with row of slender spinules. Arc of somewhat larger, graduated spinules forming transverse crest on inner proximal portion of dorsal surface. Longitudinal row of very short spinules ranging from behind point of insertion of dorsal seta to apex of ramus. Inner margin with medial group of fine hairs and distal group of minute spinules. Caudal setae (Fig. 1) as usual for *Paracamptus*, outer and inner setae of subequal size, length less than that of ramus; middle seta well developed, base enlarged, unjointed; length less than that of urosome (equaling a little more than segments 4 and 5 plus ramus) and from 2.2 to 2.9 times length of ramus.

Antennule (Fig. 7) 8-segmented; without plumose setae; aesthete of segment 4 reaching to end of antennule; outer setae of two apical segments on segmented bases. Exopod of antenna (Fig. 10) 2-segmented; first segment with plumose



FIGS. 1–16.—*Paracamptus reductus*, n. sp.: 1, Female, urosome ventral; 2, female, detail distal segments of urosome and caudal ramus, dorsal; 3, female, caudal ramus, ventral; 4, male, detail distal segment of urosome and caudal ramus, dorsal; 5, female, mandible palp; 6, male, antennule; 7, female, antennule and rostrum; 8, female, leg 4, with detail inner distal edge of basipod 2; 9, female, leg 1; 10, female, exopod of antenna; 11, female, leg 5; 12, male, legs 5 and 6; 13, female, detail of genital area; 14, female, leg 2, exopod segment 3; 15, male, leg 4; 16, male, leg 3.

seta; second with subapical plumose seta and very stout, unornamented apical spine. Mandible palp (Fig. 5) 1-segmented, with one subapical and three apical setae.

Leg 1 (Fig. 9) with 3-segmented exopod and 2-segmented endopod; exopod shorter than endopod, reaching to about proximal third of apical endopod segment. Endopod segment 1 wider and a little longer than segment 2, with short inner seta. Segment 2 narrowed, with short inner seta distally and two long, curved apical setae of the modified type found on apical exopod segment; inner seta longer than outer and both longer than endopod; relative length of outer seta, inner seta and endopod, 22:30:17.

Legs 2–4 with 3-segmented exopods. Exopod segment 2 always with inner seta. Exopod segment 3 with two outer and two terminal spines of which the inner is the longer; inner spiniform seta on legs 2 and 3 (Fig. 14), absent on leg 4. Endopods lacking, though usually minute setae present in usual position of endopod (Fig. 8).

Leg 5 (Fig. 11). Distal segment 2, length about 2 times its width; all five setae similar to one another, sparsely plumose; seta 4 the longest, seta 5 the shortest; relative length of setae to one another (from outer edge), 19:21:22:25:16. Basal segment, outer portion of inner expansion bearing the first two setae produced beyond the rest of segment, reaching to about middle of segment 2; relative length of setae to one another, 19:27:15:13:10.

MALE: Habitus as in female. Caudal ramus (Fig. 4) differing from female in being shorter than outer margin of last body segment (about 14:20). Armature similar; spinal arc on proximal dorsal face accompanied by distinct ridgelike sclerotization. Dorsal seta placed at about distal third; distad to it a short, longitudinal row of 3–4 spines.

Antennule (Fig. 6) 8-segmented, third and fourth segments imperfectly separated into additional segments. Fourth segment dilated and bearing short, stout setae. Three segments beyond geniculation, apical segment shorter than two preceding segments, apex constricted and produced beyond insertion of terminal setae; proximal, lateral setae with segmented bases as in female.

Leg 1 as in female. Legs 2 and 4 lacking endopods (no minute setae found as in female). Leg 3 (Fig. 16) with 3-segmented endopod reaching to end of exopod 2; its basal segment without inner seta; apophysis well developed, reaching to end of exopod, its total length greater than that of endopod; third segment with two subequal, apical setae also reaching to near end of exopod, their length subequal to that of endopod.

Leg 4 (Fig. 15), exopod with same setation as in female but somewhat modified. Outer distal corner of segment 2 more enlarged and outer spine much more recurved than in female. Exopod segment 3 reduced in size, its length subequal to that of exopod 2 rather than longer as in female.

Leg 5 (Fig. 12). Distal segment 2 small, length about 1.5 times the width, with five setae; four outer setae of different lengths but of similar stoutness, all plumose; innermost seta reduced, shorter than segment; relative length of setae to one another (from outer to inner), 5:7:11:16:4. Inner basal portions of leg not divided, with two spiniform setae borne on slight production of segment, inner seta subequal in length to longest (fourth) seta of segment 2, and a little more than twice length of outer (17:7). Leg 6 (Fig. 12) with three setae, the innermost stout and spiniform, subequal to slender outer seta; both outer and innermost setae a little longer than longest seta (second basal) of leg 5.

Discussion.—Only two species of *Paracamptus* are known: *P. schmeili* (Mrazek) from Europe and *P. baikalensis* Borutzky from Lake Baikal in Asia. Several varieties have been named for *schmeili* but Lang (1948), on the basis of the extreme variability found in specimens he studied from Sweden, considers that none can be recognized as subspecies.

P. baikalensis, known only from the female, is separable from *schmeili* on the basis of the much shorter caudal ramus (wider than long) and the lack of reduction and modification of the middle seta of the second segment of the fifth leg. The setae of the fifth leg of *schmeili* are reportedly variable, but according to Lang, the third or middle seta of the second segment is always finer than the others, nonplumose, usually shorter than the outer setae, and always shorter than the inner setae. This seta in the new Alaskan species *reductus* is not modified or reduced, being plumose and of similar stoutness to the other setae in both sexes. The occurrence of this character in ♀ species so distinct as *reductus* gives strength to its importance as a specific differentiation between *baikalensis* and *schmeili*, a point which Lang questioned.

In comparing *reductus* with the other two known species, the most obvious difference is the lack of the endopods of legs 2–4, an unusual character in free-living copepods and not previously known in the Canthocamptidae. Such a lack has been recorded in the Harpacticoida for two other genera, *Paranannopus* (family Cletodidae) and *Leptopsyllus* (family Paramesochridae). The endopods of these legs in *Paracamptus* are reduced in segmentation, size and armature, but the forms that have been described have shown no indication of intermediate conditions leading to the complete loss of the endopod. If one were dealing with only a single specimen, a single sex, or a collection from a single lake, it might be suspected that an anomalous condition exists. But all the specimens examined lack the endopods, and the species is known from two widely separated lakes of different drainage systems. Possibly the strongest reason for not regarding this condition as anomalous is the fact that the endopods are lacking not only in the female, but also on legs 2 and 4 of the male, although the modified copulatory endopod of the third leg is normally and strongly developed. Additional evidence that the complete loss of the endopod is normal for this species, is found in the second basal segment, which is likewise reduced. This is shown clearly in figure 8. The inner portion of the basal segment is slanted abruptly upwards just beyond the spinous point which is present between the exopod and endopod in all *Paracamptus*. That the minute setae present in the female may be regarded as remnants of the endopod is suggested by their position just beyond this spinous point where the endopod would normally be attached.

Even if the endopods were normally developed, *P. reductus* has other characters which would separate it from *baikalensis* or from any of the forms of *schmeili*. The caudal ramus is shaped much like that of typical *schmeili*, but the armature apparently differs in part. In *reductus*, there is a basal crest of strong spines instead of hairs. The longitudinal row of spinules running from the base of the dorsal seta to the apex of the ramus in both sexes of *reductus* has not been shown in any figures of *schmeili*. The great length of the outer apical seta of the endopod of the first leg may be peculiar to *reductus*; the reduced inner seta present in *reductus* is usually absent in *schmeili*. The fifth legs of both sexes differ from *schmeili* in that the third seta of the second segment is similar to the other setae. The basal portion of this leg in the female of *reductus* differs from both *schmeili* and *baikalensis* in the prominent production of the outer portion bearing the first two setae. The endopod of leg 3 of the male has a single apical seta in *schmeili* and the presence of two apical setae in *reductus* appears to constitute a further distinction of the new species.

LITERATURE CITED

LANG, KARL. *Monographie der Harpacticiden*, 2 vols.: 1683 pp. Stockholm, 1948.

WILSON, MILDRED STRATTON. *North American harpacticoid copepods 1. Comments on the known fresh-water species of the Canthocamptidae.* Trans. Amer. Micr. Soc. 75(3): 290–307, illus. 1956.

GRANTS-IN-AID

The Committee on Grants-in-Aid for Research wishes to remind Academy members that the Academy has a few hundred dollars available to aid those engaged in research. The sum is not large but is adequate to supply special equipment or supplies needed in research. The funds are advanced to the Academy by the AAAS and are available to high-school students, college students at the undergraduate or graduate level, and to instructors. Requests should be addressed to either Dr. H. Specht, of the National Institutes of Health, or to the undersigned.

WALTER J. HAMER
Chairman, Committee on Grants-in-Aid for Research

MAMMALOGY.—*Little-known reference to name of a harbor seal.* VICTOR B. SCHEFFER, U. S. Fish and Wildlife Service. (Communicated by Herbert Friedmann.)

(Received September 12, 1956)

About 1950, we received from its author a reprint of an article in Japanese, as follows: INUKAI, TETSUO. Hair seals (azarashi) in our northern waters [i.e., Japanese waters]. Shokubutsu oyobi Dobutsu [Botany and Zoology], Yokando, Tokyo, **10** (10): 927–932, text figs. 1–5 [fig. 1 in 2 parts], 1 October; no. 11, p. 1025–1030, text figs. 6–7, 1 November. 1942. [In the reprint, no. 10, is part 1, p. 37–42; no. 11 is part 2, p. 41–46.]

Among materials brought back by Ford Wilke, U. S. Fish and Wildlife Service, from the National Resources Section, General Headquarters, Supreme Commander for Allied Powers, Tokyo, about 1950, is a translation of Inukai's article, translator's name not shown. We quote excerpts, as follows:

"I think these four species [ribbon seal, bearded seal, ringed seal, and harbor seal] are enough for the hair seal classification [to date] . . . In addition I tell you that another species 'zenigata-azarashi' is recognizable besides the above four" (p. 928).

"This species appears black as a whole and people call it 'Kuro'—black. It has spots all over the body, white ones about 3 cm. long and 1 cm. wide which have coin-shaped black spots inside them. These coin-shaped spots look like the spots of the 'fuiri-azarashi' [quite certainly the ringed seal, *Phoca hispida*], clear on the back and dim on the belly (fig. 4). The body size is almost the same as 'gomafu-azarashi' [quite certainly the harbor seal, *Phoca vitulina*] but many of them are rather small. They live mostly in the southern Kuriles and their distribution is limited to a small area on the Pacific coast. Their western limit is Erimo Zaki [southeastern Hokkaido], the eastern limit is northern Kuriles. Their skulls resemble 'gomafu' and they live with them except during the breeding season. I think they are a variation of the 'gomafu'. Their actions are faster than 'gomafu'; their legs are larger; they run away very quickly. I suggest *Phoca uochotensis* [read *ochotensis*; certainly a typesetter's error, since the name is spelled correctly elsewhere in the paper] var. *kurilensis* for this species. Occasionally, skins that appear intermediate between those are found in the southern Kuriles (fig. 5)." (This paragraph, including figs. 4 and 5, on p. 930.)

Fig. 4 represents the flat skin of a male, locality not specified. In our opinion, the pattern is that of a dark harbor seal, *P. vitulina*. Fig. 5 represents the flat skin of a male, apparently a medium-dark harbor seal. No measurements of body or skull for "zenigata" are given. No specimens were reported saved.

Farther along in his paper (pp. 930–1026) Inukai gives certain biological data for "zenigata." In a commercial catch of seals from the southern Kuriles from early July to early September, there were 139 harbor seals, 42 ringed seals, and 21 "zenigata". The copulating season for "zenigata" is said to be in mid-June, a little later than for the habor seals. This information, if true, would be extremely difficult to obtain. It indicates, however, that "zenigata" are adults and that the name is not a collective one for subadults. Pups are born with yellowish-white, long, downy hair—characteristic both of ringed and harbor seals. Mother seals carrying young on their backs are seen around Erimo Zaki in May—an observation which might be made both of ringed and harbor seals. " 'Zenigata' . . . seems to have the same food habits as 'gomafu' " . We take this to mean that "zenigata" feeds, like the harbor seal, on fish, squid, octopus, and larger shellfish, rather than like the ringed seal on macroplankton.

We call attention to the name *P. kurilensis* since it does not appear in the Zoological Record or in Ellerman and Morrison-Scott's "Check List of Palaearctic and Indian Mammals 1758 to 1946." Pending further study, we suggest that *P. kurilensis* be regarded as one of the approximately ten synonyms of *Phoca vitulina largha* Pallsa, 1811.

ENTOMOLOGY.—*A review of the psocids, or book-lice and bark-lice, of Texas (Psocoptera).*[1] EDWARD L. MOCKFORD, University of Illinois, and ASHLEY B. GURNEY, U. S. Department of Agriculture.

(Received August 8, 1956)

The psocids (Psocoptera) are one of the minor orders of insects, with only about 145 species recorded from the United States. Their obscure habits, small size, and limited importance are probably responsible for their nearly complete neglect by all but a very few entomologists, and it is probable that intensive study will double the number of known Nearctic species. This paper is designed to lay a foundation for future work on the psocids of Texas.

The principal specimens on which this report is based were secured by the junior author in 1951, when he visited Texas in company with O. L. Cartwright and, between September 18 and October 8, collected insects at about 55 localities in the eastern, central, and southern parts of the State. In addition to reporting on this collection, we have included information on other available Texas material, and previous records in the literature are also summarized.

It should be realized that the 1951 trip was only a beginning of a survey of the psocid fauna of the State as a whole, since it covered less than a third of Texas in a very hurried manner at one season of the year, and the beating of foliage was the chief collecting method utilized. The biotic provinces and physiographic regions of Texas are quite varied, and future collecting probably will disclose many additional species. Several publications on Texas natural areas may be helpful to future students. Blair (1950) described six principal biotic provinces, these representing some modifications of Dice's (1943) results and a considerable advance over Bailey's (1905) grouping, which consisted of traditional life zones based largely on temperature. Taylor (1945) and Russell (1945) have contributed other general works dealing with factors that influence the distribution of animals of Texas.

The largest number of specimens taken in 1951 were beaten from foliage into a black umbrella, picked from the umbrella with a camel-hair brush dipped in alcohol, and placed in 70-percent alcohol. Others were found under bark, and a few were attracted to lights at night. Sifting ground litter and examining the outer surface of tree trunks were methods little utilized, though usually these are helpful and should be used in future psocid collecting. In general, psocids did not appear abundant until the Rio Grande Valley from Mission eastward was reached, and the very dry conditions over most of the State in 1951 may have been partly responsible for their scarcity. From Mission to Brownsville and along the east coast, palm trees, especially *Washingtonia filifera* Wendl. (introduced, probably from California), harbored many psocids. The dead fronds of untrimmed *Washingtonia* trees were excellent psocid habitats, especially the lower surfaces of the more apical portions.

Special mention should be made of the stands of the sabal or palmetto, *Sabal texana* Becc., near Brownsville. Originally there were extensive groves of the sabal on the delta about the mouth of the Rio Grande. Now, except for scattered remnants throughout the delta and extending as far north of Brownsville as Olmito, and about 80 miles west from the Gulf, native stands are largely restricted to the Southmost and Rabb "bends" of the Rio Grande, located about 6 to 12 miles southeast of downtown Brownsville. Several very profitable visits were made in 1951 to that portion of the Rabb Grove, which is owned by Mrs. R. M. McCormick, about 7 miles east-southeast of Brownsville. A full account of the sabal, with special reference to the groves at Southmost, is that of Davis (1942); an earlier review is by Small (1927), and

[1] Field work by the junior author was supported in part by a grant from the Penrose Fund of the American Philosophical Society.

Bailey (1944) has revised the group. This area south and southeast of Brownsville is the most nearly tropical portion of Texas, though there is a fairly severe frost about every 6 to 10 years, and light frosts are not rare. Although several plants and animals of the area are essentially tropical species, the area can not be considered part of the true Tropical Zone. A valuable summary of the plants and zonal affinities is by Clover (1937). The commercial growing of bananas and other tropical fruits is impossible in view of the occasional killing frosts. One of the most severe freezes, with temperatures below 19° F., occurred in early 1951, and is reviewed by Gunter and Hildebrand (1951). Goldman (1951, pp. 259–267) described Matamoros and nearby areas of northern Tamaulipas as Lower Austral, though invaded by some Arid Upper Tropical Subzone elements. Students of broad distributional problems may be assisted by Galtsoff, et al. (1954).

The pioneer worker on Texas psocids was Frank Aaron (1862–1947), of Philadelphia, Pa., whose life was reviewed by Calvert (1947). Aaron made a hunting trip on the plains of southwestern Texas when 16 years old. He collected Texas insects extensively in 1884, and it was probably then that he collected the five psocids he described in 1886. He discussed (1884) collecting insects, evidently mostly Lepidoptera, in the vicinity of Corpus Christi, visiting "heavy bottom lands," the coastal area, and "many broad pastures." He also made a wagon trip, for collecting purposes, of over 100 miles along the coast north of Corpus Christi. While we have not seen all the type series of his species, which are preserved in the Academy of Natural Sciences of Philadelphia, several specimens have been examined and found to bear no collecting data except a simple label, "Tex." Many natural habitats visited by Aaron probably have been greatly altered by agricultural and industrial developments; Cook (1908) has dealt with such changes in Texas.

Nathan Banks (1868–1953), for many years the only American student of psocids, described five psocids from Texas, and others described by him doubtless will be found in the State eventually, in addition to some here recorded for the first time. P. J. Chapman (1930), in what was the first thoroughly modern important systematic work on Nearctic psocids, contributed very few Texas records additional to citing the Aaron and Banks types. Neither Chapman himself, nor C. R. Crosby and S. C. Bishop, who elsewhere in the United States were extensive collectors of material studied by Chapman, are mentioned as the collectors of any Texas psocids.

The beginning student of psocids is advised to consult such general works as Badonnel (1943, 1951) and Borrow and DeLong (1954). For identification of material Chapman's paper (1930) is quite basic for the genera he treated, and there is a growing list of recent revisionary works. The classification of families and higher groups in this paper follows that used by Badonnel (1951).

Faunal affinities: Of the 47 species mentioned in this paper, 15 are generally distributed throughout the eastern half of the United States. These are as follows: *Echmepteryx hageni, Trogium pulsatorium, Psyllipsocus ramburii, Lachesilla forcepeta, L. major, L. nubilis, L. pedicularia, Ectopsocopsis pumilis, Peripsocus madidus, Psocus pollutus, P. bisignatus, Trichadenotecnum unum, Cerastipsocus venosus, Metylophorus purus,* and *Blaste quieta.* Of these, three are commonly spread by commerce and are found on both sides of the Atlantic. *Trogium pulsatorium* was with little doubt introduced into Texas by commerce since it is exclusively domestic in North America. *Lachesilla pedicularia* may be native to both Europe and North America, since it occurs commonly in both domestic and outdoor habitats in both continents. *Psyllipsocus ramburii* was probably introduced from Europe into domestic situations in North America, but it may be native to caves in Texas. It has not been recorded from as far south as Texas in dwellings, and the Texas specimens differ slightly in appearance from northern domestic material. Badonnel (1955) has recorded it from a cave in Angola.

Two species were probably introduced into Texas by commerce but are scarce in

North America generally. These are *Ectopsocus richardsi* and *Lepinotus reticulatus*. *E. richardsi* is not recorded in the North American literature; both the Texas specimens and material taken in Florida by the senior author were from domestic habitats. It has also been found in large numbers in a Boston (Mass.) warehouse. *L. reticulatus* has been recorded from only two other North American localities (Gurney, 1949).

Cerobasis guestfalica, taken at one Texas locality, is probably native to North America as well as Europe. It is generally distributed throughout the western States (Colorado, Utah, California, Washington, Arizona) and has been found at one Florida locality (unpublished records of senior author).

Twelve Texas species show a definite tropical affinity. These include the species of *Rhyopsocus*, *Tapinella*, and *Archipsocus*, *Pseudocaecilius citricola*, *Pseudoseopsis hellmani* *Psocathropos* sp., and *Psyllipsocus oculatus*. The first five genera of this list are largely tropical and reach their northern limit around the Gulf of Mexico and up the southeastern Atlantic Coast. *Tapinella* has not previously been recorded in the North American literature. *Psyllipsocus oculatus* was previously of uncertain locality as the holotype was found on plants from Mexico at a quarantine station at Laredo, Tex.

The family Amphientomidae, represented in Texas by *Pseudoseopsis hellmani*, n. sp., has not previously been recorded from the United States. It is well represented in tropical South America, Africa, and India. The genus *Pseudoseopsis* contains only one other species, *P. vilhenai* Badonnel from Angola. The generic assignment of the Texas species is tentative, and collection of additional material may show that a new genus is desirable for it.

Acknowledgments: The 1951 trip of the junior author was greatly aided by a grant from the Penrose Fund of the American Philosophical Society. He is also grateful for cooperation and courtesies received during the trip from the following entomologists at the places mentioned: O. P. Breland (Austin); L. J. Bottimer, C. L. Smith (Kerrville); J. B. R. Leary (Laredo); Paul C. Avery (Mission); F. A. Allen, R. A. Alexander, O. D. Deputy, R. B. Lattimore, C. H. Wallis, A. L. Williamson (Brownsville). Laboratory facilities and/or assistance in reaching collecting localities at Kerrville, Laredo, Mission, and Brownsville were generously provided by workers of the U. S. Department of Agriculture. Dr. B. C. Tharp, of the University of Texas, and Mrs. L. Irby Davis, of Harlingen, Tex., have since been of much assistance concerning the distribution of *Sabal texana*.

Suborder TROGIOMORPHA Roesler

Group ATROPETAE Pearman

Family LEPIDOPSOCIDAE Enderlein

Echmepteryx hageni (Packard)

Amphientomum hageni Packard, 1870, p. 405; *Echmepteryx agilis* Aaron, 1886, p. 17; *Echmepteryx hageni* (Parkard) Enderlein, 1906, p. 320; *id.*, Mockford 1955, p. 438.

Ten miles west of Orange, Oct. 8, 1951, beating oaks, 1 ♀, A. B. Gurney.

Family TROGIIDAE Enderlein

Lepinotus reticulatus Enderlein

Lepinotus reticulatus Enderlein, 1905, p. 31; *id.*, Gurney, 1949, p. 63.

Kerrville, Sept. 21, 1951, in floor litter of chicken house, 1 ♀, A. B. Gurney.

Trogium pulsatorium (Linnaeus)

Termes pulsatorius Linnaeus, 1758, p. 610. Synonymy discussed by Gurney, 1939.

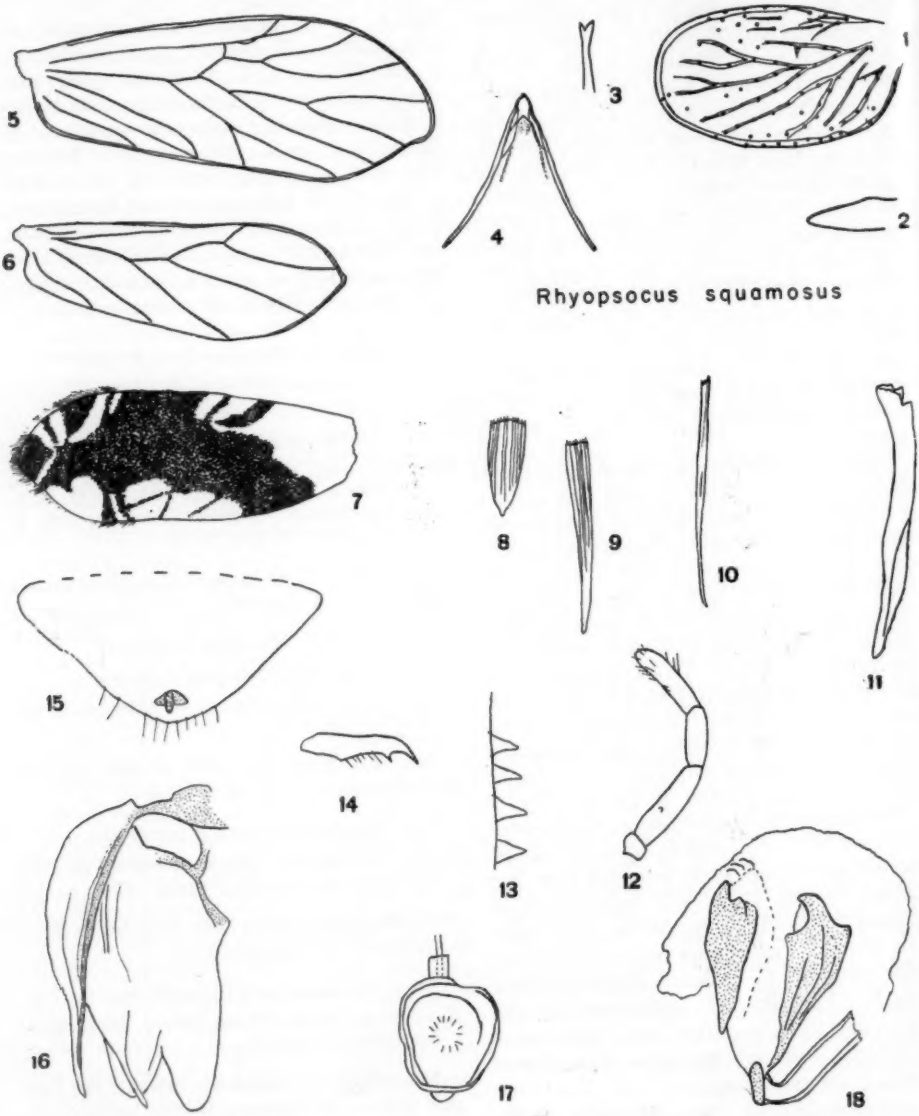
Corpus Christi, Aug. 1945, from house, 9 ♀, 4 nymphs, F. R. DuChanois.

Cerobasis guestfalica (Kolbe)

Hyperetes guestfalicus Kolbe, 1880, p. 132 (original description examined).

The spelling of *guestfalica* agrees with the feminine gender of *Cerobasis*, unlike *lapidarius* as given by Badonnel (1955, p. 32). The combination *C. muraria* used by Kolbe (1882, p. 212) also agrees. *Cerobasis* is comparable in gender to *Goniobasis* (shown as feminine by Brown, 1954, p. 124). Generic synonymy has been discussed by Gurney (1949) and given earlier by Roesler (1944, p. 131).

Kerrville State Park, Sept. 20, 1951, 7 ♀, 3 nymphs; Kerrville: U. S. Dept. of Agriculture



FIGS. 1–4.—*Rhyopsocus squamosus*, n. sp., male: 1, Front wing; 2, hind wing; 3, tip of lacinia; 4, parameres. FIGS. 5–18.—*Pseudoseopsis hellmani*, n. sp., female: 5, Front wing; 6, hind wing; 7, front wing, showing pattern of scales; 8, 9, scales of wing membrane; 10, scale from margin of wing; 11, lacinia; 12, maxillary palpus; 13, spines of row on front femur; 14, tarsal claw; 15, subgenital plate; 16, gonapophyses; 17, plate of opening of spermathecal duct; 18, sclerotization beside spermatheca.

Laboratory, Sept. 21, 1951, beating cedars, 5 ♀, 3 nymphs. Both collections by A. B. Gurney.

Family PSOQUILLIDAE Pearman

Rhyopsocus bentonae Sommerman

Rhyopsocus bentonae Sommerman, 1956, p. 146.

Corpus Christi, Oct. 6, 1951, beating palms, 1 ♂, 1 ♀, A. B. Gurney.

Rhyopsocus phillipsae Sommerman

Rhyopsocus phillipsae Sommerman, 1956, p. 146.

Ten miles west of Orange, Oct. 8, 1951, beating oaks, 1 ♂, A. B. Gurney.

Rhyopsocus squamosus, n. sp.

Figs. 1–4

Diagnosis.—Differs from *R. speciophilus disparilis* (Pearman), and presumably *R. s. speciophilus* (Enderlein), in smaller size (body length of that species 1.4 mm) and relatively shorter wings. Differs from *R. afer* (Badonnel) in paler color of head and thorax, relatively shorter wings, and in details of male genitalia. Differs from *R. bentonae* Sommerman in microptery and in details of male genitalia. Differs from *R. phillipsae* Sommerman in lack of abdominal tergal lobes of male, genitalic details, and shorter wings.

Holotype ♂.—Measurements: Total body length 1.17 mm; forewing length 0.37 mm; hind tibia length 0.20 mm; hind tarsus: T_1 0.13 mm, T_2 0.04 mm, T_3 0.04 mm.

Morphology.—Brachypterous; forewings extending to about half length of abdomen and showing very faint venation (Fig. 1). Hindwings (Fig. 2) slightly longer than metathorax. IO/D = 1.62; PO/D[2] = 0.50. Anteroposterior diameter of eye 0.173 mm. Epicranial and frontal sutures present. Ocelli absent. Lacinia (Fig. 3) of usual type for the genus. Terminal segment of maxillary palpus clavate. Thoracic nota of the short-winged type with no prominent lobes. All tibiae with three terminal spurs. Hypandrium unmodified. Parameres (Fig. 4) long, slender, diverging anteriorly. Sclerites of the penis canal complex, lacking denticles. Paraprocts each with a strong spine near inner margin and several cilia apparently lacking basal rosettes.

Color (from paratype in alcohol).—Eyes black; three brown pigment spots in ocellar positions; a few other tiny brown spots in front, otherwise head, body, and appendages pale straw-colored.

Type locality.—Texas, Olmito Resaca, near Brownsville, holotype ♂, 1 paratype, ♂, 1 nymph, Oct. 4, 1951, on vegetation, A. B. Gurney.

Types in U. S. National Museum, no. 62261.

Discussion.—This species is considered a brachypterous *Rhyopsocus* because its hind wings and lack of ocelli exclude it from the genera *Eosilla* Rib. and *Empheriella* Enderlein, and its *Rhyopsocus*-type lacinia exclude it from *Balliella* Badonnel. We consider *Deipnopsocus* Enderlein and *Rhyopsocopsis* Pearman (new synonymy) synonyms of *Rhyopsocus* Hagen. *Deipnopsocus* has already been placed in synonymy by Badonnel (1949, p. 29).

Rhyopsocus texanus (Banks)

Deipnopsocus texanus Banks, 1930, p. 223.

Type locality, Brownsville. This species cannot be recognized from the original description. It is discussed by Sommerman (1956). The type is in the Museum of Comparative Zoology, Cambridge, Mass.

Group PSOCATROPETAE Pearman

Family PSYLLIPSOCIDAE Enderlein

Psyllipsocus ramburii Selys-Longchamps

Psyllipsocus ramburii Selys-Longchamps, 1872, p. 146. Synonymy listed by Gurney, 1943.

Sonora, Wyatt Cave, July 23, 1926, 1 ♀; Hayes County: San Marcos, Sept. 15, 1953, under rocks in entrance to Ezel's Cave, 5 ♀, 2 nymphs, E. L. Mockford.

Psyllipsocus oculatus Gurney

Figs. 52–53

Psyllipsocus oculatus Gurney 1943, p. 214.

The female of this species, previously undescribed, is similar to the male in size and color. The gonapophyses (Fig. 53) differ from those of the other American species in possessing a rudimentary internal valve.

[2] It is not clear from Badonnel's explanation of PO (Badonnel, 1955, p. 18) exactly what is meant. As stated, it is a simple linear measurement which should be expressed in units and which would not show the prominence of the eye. In the text of Badonnel's paper, no units accompany the figures. Figures of comparable size, and which do express the prominence of the eye fairly satisfactorily are obtained by dividing the transverse diameter by the anteroposterior diameter (both measurements taken in dorsal view of the head.) Our figures for PO/D were obtained in this manner.

Mission, Sept. 30, 1951, beating palms, 1 ♂, 1 ♀, A. B. Gurney.

Psocathropos sp.

This species was discussed by Gurney (1949) as *P. lachlani* Ribaga, but until more information is available it may be best to avoid applying that specific name to our United States population. We are using Ribaga's original spelling of the generic name.

Houston, in house, July 26, 1941, M. Cockrell, 3 ♂, 2 ♀, 2 nymphs; Brownsville, on loose paper in laboratory, Oct. 3, 1951, A. B. Gurney, 1 ♀; Brownsville, in house, Oct. 31, 1951, F. A. Allen, 3 ♂, 1 ♀, 2 nymphs.

Suborder TROCTOMORPHA Roesler

Group AMPHIENTOMETAE Pearman

Family AMPHIENTOMIDAE Enderlein

Pseudoseopsis hellmani, n. sp.

Figs. 5–18

Diagnosis.—Differs from the African species *P. vilhenai* Badonnel in presence of ocelli and in shape of the gonapophyses of segment 9.

Holotype ♀.—Measurements: Total body length 2.83 mm; forewing length 2.73 mm; hindwing length 2.23 mm; hind tibia length 1.07 mm; hind tarsus: T_1 0.67 mm, T_2 0.107 mm, T_3 0.107 mm.

Morphology (from holotype and paratypes).—Eyes bare, their posterior margins coinciding with the straight posterior margin of the vertex viewed from above. Three distinct ocelli located far apart, the laterals immediately beyond and below ends of frontal sutures and near compound eyes. Antennae of 12 segments, the basal flagellar segments quite long. Numerous indistinct striae on all flagellar segments, very close together toward the tip. Maxillary palpi covered with tiny hairs, interspersed with larger hairs arranged roughly in rows encircling the segments. Second segment showing three papillae (sensillae?) on one palpus of a paratype, only one on the other palpus; third segment somewhat shorter than second and fourth. Lacinia as in Fig. 11, slightly curved near tip. Forewing (Fig. 5) with a slightly extended apex, the extended portion actually rounded. Distal portion of Sc distinct. Scales of membrane mostly short and wide with the apex truncate (Fig. 8), but some quite slender (Fig. 9). Marginal scales slender; some extremely slender with the apex slightly emarginate (Fig. 10). Hind wing with acute apex; vein R_1 nearly reaching wing margin; vein Ax strongly curved. Scales mostly slender; some marginal scales extremely long and slender with emarginate apices.

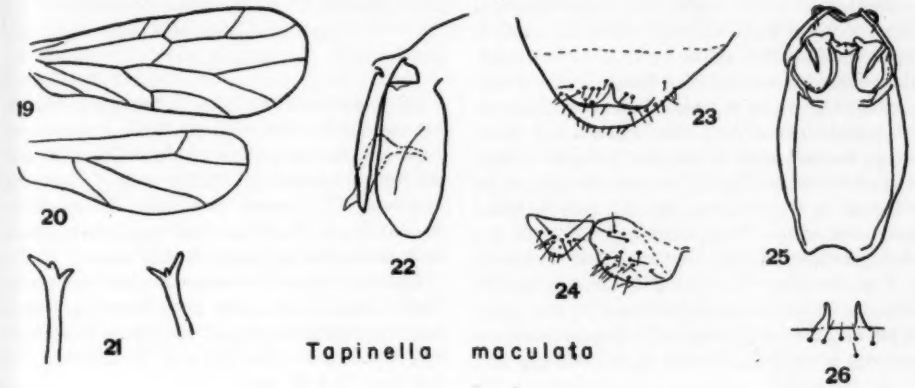
Anterior femur with a row of 25 spines (Fig. 13) with wide bases, not articulated. Other spination of legs summarized in Table 1. Twenty-two ctenidiobothria on T_1 of hind leg. A small comb running to the claw at apex of T_3 of each leg. Claw with single preapical tooth and a row of tiny hairs ventrally (Fig. 14).

Genitalia and terminalia.—Subgenital plate (Fig. 15) with a sclerotized process. Gonapophyses (Fig. 16): ventral valve long, slender, acuminate apically with a sclerotized inner edge; dorsal valve acuminate apically; lobes of external valve rounded apically. Sclerite of spermathecal opening (Fig. 17) and sclerite beside spermatheca (Fig. 18) as illustrated. Epiproct and paraprocts covered with long, slender hairs; paraprocts each with a field of hairs with basal rosettes.

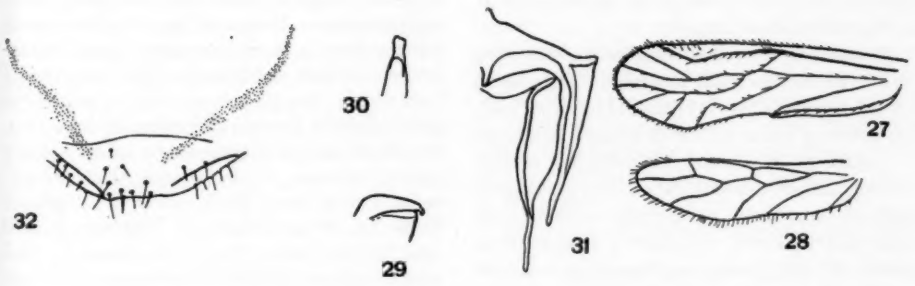
Scale color pattern (from dry specimens).—Head except eyes covered with slender, curved pale-gray scales. Mesonotum covered with short, wide white scales. Femora covered with dirty-gray and brown scales; fore and middle tibiae

TABLE 1.—SPINATION OF LEGS IN PSEUDOSEOPSIS HELLMANI

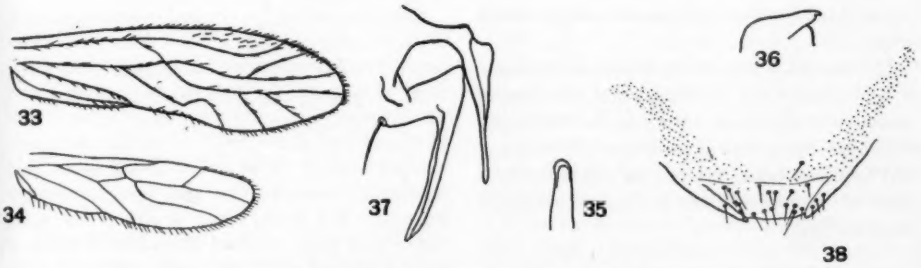
Region of leg	Number of spines on—		
	Prothoracic leg	Mesothoracic leg	Metathoracic leg
Femur apex	None	1 lateral 1 curved, external	1 lateral 1 curved, external
Body of tibia	None	1, ⅓ distance from base 1 near apex	External—1, ⅛ from base 1, ¾ from base 2, ⅜ from base 2, ½ from base Lateral 1, ⅝ from base Internal 1, ⅜ from base 2, ⅝ from base 2, ¾ from base
Tibia apex	1	5	6
First tarsal segment	3 near apex, ventral 2 apical, ventral	3 near apex, ventral 2 apical, ventral	3 near apex, ventral 2 apical, ventral
Second tarsal segment	1 apical, ventral	2 apical, ventral	1 apical, ventral
Third tarsal segment	None	None	None



Tapinella maculata



Caecilius palmarum



Caecilius caloclypeus

FIGS. 19–24.—*Tapinella maculata*, n. sp., female; 25–26, same, male: 19, Front wing; 20, hind wing; 21, tips of laciniae; 22, gonapophyses; 23, subgenital plate; 24, epiproct and paraproct; 25, phallic frame; 26, posterior margin of 9th abdominal tergite. FIGS. 27–32.—*Caecilius palmarum*, n. sp., female: 27, Front wing; 28, hind wing; 29, tip of mandible; 30, tip of lacinia; 31, gonapophyses; 32, subgenital plate. FIGS. 33–38.—*Caecilius caloclypeus*, n. sp., female: 33, Front wing; 34, hind wing; 35, tip of lacinia; 36, tip of mandible; 37, gonapophyses; 38, subgenital plate.

covered with brown scales except for an apical band of white scales on each. Hind tibia with a basal, medial, and apical band of white scales, the remainder covered with brown scales. Tarsi: each T_1 with an apical band of dirty white scales, the remainders covered with brown scales. Forewings marked with a complex pattern of gray and white scales (Fig. 7); in areas of white scales adjacent to the wing margin, the long marginal scales are white. Hind wings not visible on the dry specimens. Scales very sparse on abdomen.

Type locality.—Texas, Ezel's Cave (near San Marcos, Hayes County), holotype ♀, 4 ♀ paratypes and 2 nymphs, Sept. 15, 1953, on limestone outcrop at mouth of cave, R. E. Hellman and E. L. Mockford.

Holotype and one *paratype* in U. S. National Museum, no. 63276; remaining paratypes in E. L. Mockford Collection.

Discussion.—We have chosen the following characters as important for generic diagnosis in the Amphientomidae: (1) Shape of forewing apex, (2) nature of spines in row on femur I (they may be numerous, wide, and unarticulated, or few, slender, and articulated), (3) number of preapical teeth on tarsal claws, (4) curvature of lacinia, (5) shape of scale apices and pattern of striation on scales, and (6) presence or absence, and size and number of sensory cones on second segment of maxillary palpi. The Texas species agrees with the genotype of *Pseudoseopsis* in four of these characters, whereas it agrees with no other closely related genus in more than three. It is also very similar to *P. vilhenai* in general shape of the wings.

This species is named for Robert E. Hellman, of New York City, a herpetologist and former classmate of the senior author at the University of Florida. His companionship and aid on many field trips, including the one on which the type series of this species was taken, are gratefully acknowledged.

Group NANOPSOCETAE Pearman

Family LIPOSCELIDAE Enderlein

Genus **Liposcelis** Motschulsky

Dr. Kathryn M. Sommerman has very kindly examined our material in this genus and informs us (in litt.) that it contains five species, three of which are described as new in a paper which she has in press.

Family PACHYTROCTIDAE Enderlein

Tapinella maculata, n. sp.

Figs. 19–24

Diagnosis.—Differs from *T. formosana* Enderlein and *Psylloneura williamsi* Banks (probably a *Tapinella*) in color, these species being pale yellow-brown, unmarked. Differs from *T. castanea* Pearman, *T. africana* Badonnel, *T. squamosa* Badonnel, and *T. curvata* Badonnel also in color, these species being largely dark brown.

Holotype ♀.—Macropterous. Measurements: Total body length 1.60 mm; forewing length 1.40 mm; hindwing length 1.07 mm; hind tibia length 0.53 mm; hind tarsus: T_1 0.24 mm, T_2 0.05 mm, T_3 0.07 mm.

Morphology.—Compound eyes not exceeding posterior margin of head. Epicranial and frontal sutures distinct. Ocellar triangle slightly nearer clypeus than posterior margin of head. Suture between clypeus and front straight when viewed from above. Mouthparts of usual type for the group. Lacinia slender, tridentate at apex (Fig. 21). Maxillary palpi lacking specialized sensory spines. Antennae of 15 segments which are secondarily ringed from the distal half of F_5 outward to the tip. Wings unmarked. Venation of usual form for the genus; closed cell absent in hind wing. Abdomen completely membranous, including genitalia. Gonapophyses as in Fig. 22, closely associated with an appendage from the paraproct, shown under the external valve in the figure. Subgenital plate bearing T-shaped sclerite with arms long and curved.

Color (in alcohol).— Ground color cream, eyes black. A pale red-brown band from each compound eye through base of antenna to about midpoint of clypeus, the two bands meeting there. An irregular dark red-brown band on each side of thorax just above coxal insertions. Abdomen marked with six series of red-brown spots from segments 1 through 8 (one spot in each series per segment): two dorsal series of rather pale spots wider than long, a paired dorso-lateral series of dark U-shaped spots with open ends of U-s directed posteriorly, and a paired ventro-lateral series of spots longer than wide.

Allotype ♂.—Apterous. Measurements: Total body length, 1.13 mm; hind tibia length 0.40 mm; hind tarsus: T_1 0.13 mm, T_2 0.05 mm, T_3 0.07 mm. Differs from holotype in smaller size, aptery and associated characters of absence of ocelli and flat notal lobes, and absence of frontal sutures. Genitalia as in Fig. 25.

Variation.—Some female paratypes are apterous, lack ocelli, and lack all trace of subdivisions of the pterothoracic tergites (in macropterous forms each pterothoracic tergite is composed of a trilobed scutum and separate scutellum); these have only a trace of frontal sutures. Among alate females much variation exists in details of venation; it is seldom bilaterally symmetrical. Variations observed are: (1) A closed cell in hind wing at point of first branching of the main vein, (2) radial branch in hindwing disconnected from main vein, (3) a closed cell in forewing formed by presence of two R-M crossveins, (4) R_s in forewing 3-branched, (5) Cu_{1b} in forewing set at angle of Cu stem, (6) R + M in forewing joined at a point.

Type locality.—Texas, Mission, holotype ♀, allotype ♂, 2 ♂ paratypes, 7 alate ♀ paratypes, 20 apterous ♀ paratypes, and 5 nymphs, Sept. 30, 1951, on palm leaves, A. B. Gurney. Other paratypes—Texas, Palm Grove near Brownsville, 5 apterous ♀, 1 nymph (not paratype), Oct. 2 and 3, 1951, beating palm leaves; Olmito Resaca, 1 apterous ♀, 1 nymph (not paratype), Oct. 4, 1951, beating vegetation; all collected by A. B. Gurney.

Types in U. S. National Museum, no. 62264.

Tapinella sp.

A single female taken at Weslaco on dead palm leaves, Oct. 1, 1951, differs from *T. maculata* in its uniform straw-brown color (slightly darker on head and terminal abdominal segments). It is probably a new species since the arms of the T-shaped sclerite are longer than in *T. maculata*.

Suborder PSOCOMORPHA Weber

Group CAECILIETAE Pearman

Family CAECILIIDAE Enderlein

Caecilius palmarum, n. sp.

Figs. 27–32

Diagnosis.—A pale yellow species, differing from the other North American species with that coloration (*C. aurantiacus* (Hagen), *C. manteri* Sommerman, *C. sommermanae* Mockford) in being marked with a brown band longitudinally through the vertex, front, and clypeus. Head and wings narrower than in these other species.

Holotype ♀.—Measurements: Total body length 2.67 mm; forewing length 2.57 mm; hindwing length 1.87 mm; hind tibia length 0.90 mm; hind tarsus: T_1 0.267 mm, T_2 0.107 mm.

Morphology.—IO/D = 1.28. Lacinia with a slender, blunt tip (Fig. 30). Tip of mandible bearing a hooked tooth. Wing venation and ciliation normal for the genus. A long fusion of R_s and M in both fore and hind wings. Gonapophyses (Fig. 31) straight with slender tips. Subgenital plate (Fig. 32) with sclerotized area in the form of a pair of slender, converging bands visible after staining.

Color (in alcohol).—Eyes black. Antennae, anal veins, and veins of apical one-third of forewing straw colored. Rest of body pale yellow except for a pale brown band from immediately anterior to occiput on vertex to lower border of clypeus, and pale brown lateral areas on thoracic tergal lobes.

Type locality.—Texas, Olmito Resaca, 9 miles north of Brownsville, holotype ♀, 50 ♀ paratypes, and 57 nymphs, Oct. 4, 1951, beating palms and palmettoes, A. B. Gurney. Other paratypes (not including nymphs), Palm Grove near Brownsville, 14 ♀, numerous nymphs, October 1 and 3, 1951, beating dead leaves, Gurney & Allen; western outskirts of Corpus Christi, 70 ♀, 24 nymphs, Oct. 6, 1951, beating palm leaves, A. B. Gurney.

Types in U. S. National Museum, no. 63237.

Caecilius calocylpeus, n. sp.

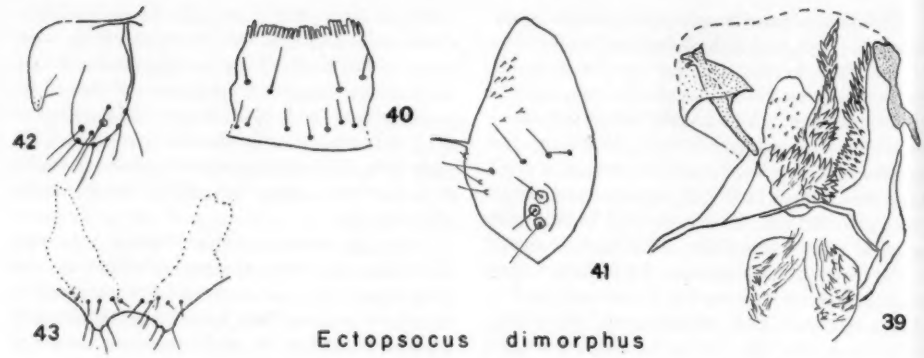
Figs. 33–38

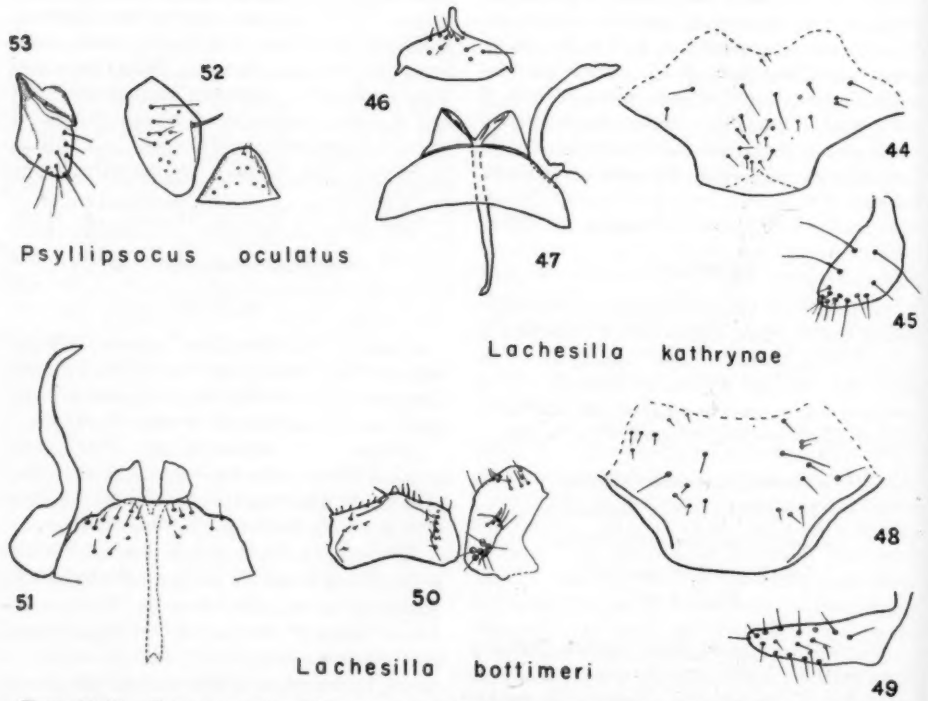
Diagnosis.—A pale-yellow species, differing from the other North American species with that coloration in that the only conspicuous body marks are several pairs of clypeal striations.

Holotype ♀.—Measurements: Total body length 2.93 mm; forewing length 2.87 mm; hindwing length 2.13 mm; hind tibia length 1.07 mm; hind tarsus: T_1 0.267 mm; T_2 0.107 mm.

Morphology.—IO/D = 1.57. Lacinia rounded at tip. Tip of mandible bearing a straight tooth. Wing venation and ciliation normal for the genus. A short fusion of both R_s and M in both fore and hind wings. Gonapophyses (Fig. 37) a pair of curved blades; valve of 9th bearing a stout basal seta. Subgenital plate (Fig. 38) with sclerotized area as a pair of converging bands, wider than in *C. palmarum*, visible after staining.

Color (in alcohol).—Eyes black. Antennae, fore tibiae and tarsi, and veins in apical half of forewing straw colored. Rest of body pale yellow except for seven pairs of purplish brown striae on clypeus and a faint purplish brown band on each





FIGS. 39–40.—*Ectopsocus dimorphus*, n. sp., male; 41–43, same, female: 39, Apex of phallic frame (somewhat distorted) and penis sclerotizations; 40, ninth abdominal tergite with comb; 41, paraproct; 42, gonapophyses; 43, subgenital plate. FIGS. 44–45.—*Lachesilla kathrynae*, n. sp., female; 46–47, same, male: 44, Subgenital plate; 45, gonapophysis; 46, epiproct; 47, hypandrium and parameres. FIGS. 48–49.—*Lachesilla bottimeri*, n. sp., female; 50–51, same, male: 48, Subgenital plate; 49, gonapophysis; 50, epiproct and paraproct; 51, hypandrium and parameres. FIGS. 52–53.—*Psyllipsocus oculatus* Gurney, female: 52, paraproct and epiproct; 53, gonapophyses. (All drawings by the senior author.)

side running the length of the lateral prothoracic sclerites.

Type locality.—Texas, Palm Grove near Brownsville, holotype ♀ and 2 nymphs, Oct. 1, 1951, beating palms. Paratypes—Mission, 1 ♀, Sept. 30, 1951, beating palmate palms; Olmito Resaca near Brownsville, 1 ♀, Oct. 4, 1951, beating palms and palmettoes. All collected by A. B. Gurney.

Types in U. S. National Museum, no. 63238.

Group HOMILOPSOCIDEA Pearman

Family PERIPSOCIDAE Pearman

Peripsocus madidus (Hagen)

Psocus madidus Hagen, 1861, p. 12. Synonymy presented by Chapman, 1930.

Bexar County, May 5, 1938, swept from peach, 4 ♂, 14 ♀, 1 nymph.

Ectopsocus richardsi (Pearman)

Chaetopsocus richardsi Pearman, 1929, p. 105; *Ectopsocus richardsi* Pearman, 1942, p. 290.

Houston, April 15, 1948, in stored rice, 3 ♂, 2 ♀, R. T. Cotton; Beaumont, July 18, 1936, cracks in floor in rice mill, 1 ♂, 1 ♀, A. L. Balzer.

Ectopsocus dimorphus, n. sp.

Figs. 39–43

Diagnosis.—Very similar to *E. pearmani* Ball of Belgian Congo, differing chiefly in shape of subgenital plate, the apical lobes being further apart in the present species; also differing slightly in several measurements. Males micropterous (nearly apterous); females dimorphic: macropterous and micropterous.

Holotype ♀.—Macropterous. Measurements: Total body length 1.43 mm; forewing length 1.40 mm; hindwing length 1.17 mm; hind tibia length 0.50 mm; hind tarsus: T_1 0.187 mm, T_2 0.080 mm.

Morphology.—Epicranial and frontal sutures distinct. Eyes small but prominent. IO/D = 2.9; PO/D = 0.65; anteroposterior diameter of eye 0.133 mm. Vertex, front, and postclypeus covered with curved setae. Antenna somewhat shorter than forewing. Ratio of f_1 to Sc+P = 1.8; ratio of f_1 to $f_2 + f_3$ = 0.76. Eight ctenidiobothria on first segment of hind tarsus; none on that of middle tarsus. Stigma sack of normal length, rounded apically. In forewing R_s meets M for a short distance, or the two are connected by a short crossvein. Hairs on wings restricted to stem of R, stem of M + Cu, and Ax in forewing; these hairs few and short. Gonapophyses (Fig. 42): internal valve very minute; ventral valve with spinulose apex; external valve a thumblike flap, mostly sclerotized, bearing 10 setae distally. Subgenital plate (Fig. 43) bilobed apically, each lobe with several marginal setae. Paraproct (Fig. 41) bearing four trichobothria and a median row of five setae; duplex spine of inner margin very minute.

Color (in alcohol).—Eyes black. Body and appendages generally tawny brown. Membranous portion of abdomen pale, ringed with brown (subcuticular pigment). Wings unmarked, slightly tawny.

Allotype ♂.—Micropterous. Measurements: Total body length 1.27 mm; hind tibia length 0.467 mm; hind tarsus: T_1 0.147 mm, T_2 0.080 mm. Differs from holotype in much smaller size and microptery; wings represented by two pairs of small fleshy lobes, each bearing a few bristles. IO/D = 2.2. PO/D = 0.6, anteroposterior diameter of eye 0.133 mm. Ocelli absent. Thoracic tergites of micropterous type, with large prothoracic tergite and pterothoracic tergites not divided into lobes. Similar in color to holotype, but abdominal rings more distinct. Each abdominal tergite bearing a distinct row of bristles. Tergite 9 adorned with a comb of teeth (Fig. 40). Penis and parameres (Fig. 39) with external parameres rather far apart so that aedeagal arch is wide. Sclerotizations of penis consisting of a pair of rods spinose apically, a hook on each side externally (not symmetrical), and other small sclerites of the canal.

Variation.—Micropterous females occur with wing pads not reaching the abdomen. These have typical undivided thoracic tergites of the short-winged type, and ocelli represented by three small subcuticular pigment spots. Setae of the vertex, front, and postclypeus are somewhat shorter than in the macropterous forms.

Type locality.—Texas, Brownwood (Brown County), holotype ♀ and a large number of macropterous paratype ♀ ♀ May 14, 1939, from peach, L. S. Jones. Allotype ♂, Texas, Tyler, Nov. 24, 1939, on cover crop in peach orchard, associated with 4 micropterous ♀ paratypes and 2 nymphs, L. D. Christensen. Other paratypes—Texas, Brownwood (Brown County), 1 macropterous ♀, March 26–27, 1939, from peach, L. S. Jones; Bangs (Brown County), 4 macropterous ♀, June 8, 1938, sweeping peach and cover crops,

Christensen et al.; Brown County, 1 micropterous ♀, 2 macropterous ♀, July 14, 1937, peach orchard, Turner & Anderson; Bexar County, 11 macropterous ♀, May 5, 1938, on peach, W. R. Turner; same locality, 1 macropterous ♀, 6 micropterous ♀, Nov. 23, 1938, on soil under grass and leaves in peach orchard, W. F. Turner; Dallas, 1 macropterous ♀, May 25, 1939, on cane, W. G. Bruce; El Paso County, 7 micropterous ♀, July 22, 1937, on soil in peach orchard, Turner & Anderson. New Mexico, Albuquerque, 8 micropterous ♀, 1 ♂, 1 nymph, March 3, 1938, from soil, L. D. Christensen; same locality, 2 micropterous ♀, December 9, 1939, from soil, L. D. Christensen. California, Cherry Valley, 3 macropterous ♀, May 7, 1937, on peach and in soil, Christensen & Jones; Hemet, 1 ♂, 1 micropterous ♀, Jan. 13, 1938, in soil, Christensen et al.; Los Angeles County, Ranger Station at west fork of San Gabriel River near Mount Wilson, elevation 3,200 feet, 1 ♂, 1 micropterous ♀, Sept. 9, 1953, in ground litter under California Live Oak, E. L. Mockford; Georgia, Decatur County, Woodruff Dam site near Florida line, 1 ♂, 1 micropterous ♀, June 2, 1953, in ground litter on hillside in newly cleared field, E. L. Mockford.

Holotype, *allotype*, and most of *paratypes* in U. S. National Museum, no. 63239.

Ectopsocopsis pumilis (Banks)

Peripsocus pumilis Banks, 1920, p. 313; *Ectopsocus pumilis* (Banks), Chapman, 1930, p. 380.

Beaumont, Oct. 8, 1951, beating palms, and in rice straw near rice experiment station, 4 ♂, 9 ♀; western outskirts of Corpus Christi, Oct. 6, 1951, beating palms, 3 ♀, 1 nymph; 9 miles north of Brownsville, Oct. 4, 1951, beating palms and palmettoes, 1 ♀, 2 nymphs. All collected by A. B. Gurney.

The genus *Ectopsocopsis* has recently been described by Badonnel (1955, pp. 185, 193).

Family Pseudocaeciliidae Pearman

Pseudocaecilius citricola (Ashmead), n. comb.

Psocus citricola Ashmead, 1879, p. 228; *Caecilius pretiosus* Banks, 1920, p. 311 (new synonymy); *Pseudocaecilius wolcotti* Banks, 1924, p. 423 (new synonymy); *Pseudocaecilius pretiosus* (Banks), Chapman, 1930, p. 332.

San Antonio, 3 ♀ (holotype and paratypes of *C. pretiosus* Banks).

Four specimens on paper points were found in the U.S. National Museum which apparently are cotypes of *Psocus citricola* Ashmead. Each bears a printed label "Jacksonville, Fla." and a handwritten label "*Psocus citricola* Ashm." The writing on the latter labels has been identified as that of Ashmead by A. B. Gahan, long a Hymenoptera specialist at the National Museum. Ashmead lived in Jacksonville when he published the description of this species, and most of his collecting was done locally. From the dry specimens it can be seen that all are the same species, a *Pseudocaecilius*. One, here selected as lectotype (U.S.-N.M. type no. 63247), has been soaked from its point in KOH solution and mounted on a slide for critical comparison with paratypes of *pretiosus* and *wolcotti* borrowed from the M.C.Z. Since no differences of specific magnitude have been noted in wing markings, venation, ciliation, measurements of head, wings, and hind legs, and number of ctenidiobothria on posterior T_1 (genitalia can not be compared as none of the *citricola* specimens have abdomens), we regard the latter two forms as synonyms of *citricola*.

Family Lachesillidae Badonnel

Lachesilla forcepeta Chapman

Lachesilla forcepeta Chapman, 1930, p. 348.

Kerrville State Park, Sept. 20, 1951, beaten from cedar, 1 ♀, 2 nymphs, A. B. Gurney.

Lachesilla major Chapman

Lachesilla forcepeta var. *major* Chapman, 1930, p. 349; *Lachesilla major* Chapman, Sommerman, 1946, p. 645.

Ten miles west of Orange, Oct. 8, 1951, beating live oak and other oaks, A. B. Gurney.

Lachesilla nubilis (Aaron)

Caecilius nubilis Aaron, 1886, p. 13; *Lachesilla nubilis* (Aaron), Chapman, 1930, p. 351.

Kerrville, Sept. 21, 1951, at light in laboratory, 1 ♂, A. B. Gurney; Dilly, Frio State Park, Sept. 24, 1951, 1 ♂, A. B. Gurney; Dallas, Apr. 5, 1905, in dry cotton bolls, 2 ♂, 3 ♀, 9 nymphs. Type locality "Southern Texas" (Aaron). See records in Sommerman, 1946, p. 648.

Lachesilla pedicularia (Linnaeus)

Hemerobius pedicularia Linnaeus, 1758, p. 551. Synonymy presented by Enderlein, 1919, p. 16.

Dallas, April 15, 1908, 1 ♂, 1 ♀. F. C. Bishopp.

Lachesilla penta Sommerman

Lachesilla penta Sommerman, 1946, p. 652.

Corpus Christi State Park, Oct. 6, 1951, beating mesquite and other vegetation, 2 ♀, 2 nymphs. Type locality, Brownsville, May 2, 1904, 1 ♂, 1 ♀, H. S. Barber.

Lachesilla rena Sommerman

Lachesilla rena Sommerman, 1946, p. 653.

A male paratype was recorded from Brownwood, Tex., by Sommerman.

Lachesilla kathrynae, n. sp.

Figs. 44–47

Diagnosis.—A member of the species group inincluding *L. anna* Sommerman, *L. chapmani* Sommerman, *L. forcepeta* Chapman, *L. contraforcepeta* Chapman, and *L. major* Chapman. Very similar to *L. chapmani*, differing in details of the genitalia in both sexes.

Holotype ♂.—Measurements: Total body length 1.33 mm; forewing length 1.53 mm; hindwing length 1.17 mm; hind tibia length 0.63 mm; hind tarsus: T_1 0.267 mm, T_2 0.080 mm.

Morphology.—Genitalia (Figs. 46, 47) with several characters typical of the species group—hypandrium of a large basal and small apical sclerite, the apical sclerite with a deep v-shaped cleft in its posterior margin. Parameres fused basally into a rod, but this rod curved rather than straight as in closely related species; parameres diverging apically, the two arms joined to the hypandrium along its cleft. Claspers curved out, stouter than in *L. chapmani*, and bulging near their apices. Paraprocts each with a ridge arising near sense tubercles and running to inner margins. Epiproct bearing a conspicuous apical tubercle as in *L. chapmani*.

Color (in alcohol).—Eyes black; antennae, wing veins, and dotted areas on vertex straw-colored. Body colorless except for red brown pigment distributed as follows: on cervical sclerites, on mesepimeral sutures, inner surfaces of coxae; two rows on each side of abdominal tergites 2 through 5, the dorsal rows continuing as weak spots to tergite 7.

Allotype ♀.—Measurements: Total body length 1.70 mm; forewing length 1.93 mm; hindwing length 1.37 mm; hind tibia length 0.73 mm; hind tarsus: T_1 0.280 mm, T_2 0.093 mm.

Morphology.—Gonapophyses (Fig. 45) a simple pair of flaps, narrowed near base and expanded preapically. Subgenital plate (Fig. 44) with an extended apical region; a more heavily sclerotized area (detectable by staining with acid fuchsin) outlined in dashed lines on the figure. Lacking a colored ventral interior plate.

Color (in alcohol).—Similar to holotype but abdominal red-brown spots present only on tergites 2 through 4.

Variation.—Some ♂ paratypes show the red-brown abdominal marks only on tergites 2 through 4, while some ♀ paratypes show them only on tergites 2 and 3.

Type locality.—Texas, Palm Grove near Brownsville, holotype ♂, allotype ♀, 5 ♂, and 17 ♀ paratypes, Oct. 3, 1951, beating dead palm leaves. Other paratypes: type locality, 5 ♂, 1 ♀, Oct. 1, 1951, beating palms; Mission, 2 ♂, 3 ♀, 1 nymph (not paratype), Sept. 30, 1951, beating palm leaves; Olmito Resaca near Brownsville, 1 ♀, Oct. 4, 1951, beating palms and palmettoes. All collected by A. B. Gurney.

Types in U. S. National Museum, no. 63240.

We are glad to dedicate this species to Dr. Kathryn M. Sommerman, in recognition of her many scholarly and highly basic studies of Nearctic psocids.

Lachesilla bottimeri, n. sp.

Figs. 48–51

Diagnosis.—A member of the same species group as *L. kathrynae*, differing from all other members in possession of very long, incurved claspers in the male (Fig. 51) and in other genitalic details in both sexes.

Holotype ♂.—Measurements: Total body length 1.40 mm, forewing length 1.67 mm; hindwing length 1.27 mm; hind tibia length 0.70 mm; hind tarsus: T_1 0.213 mm, T_2 0.093 mm.

Morphology.—Genitalia with usual characters typical of the species group. Cleft in apical sclerite of hypandrium U-shaped. Rod formed by fused parameres straight; parameres diverging apically and joined to hypandrium along U-shaped cleft. Claspers long (exceeding tip of abdomen) and slender, curving in at their tips; tips sharply pointed.

Color (in alcohol).—Eyes black; antennae and thorax above tan; dotted areas of vertex, thorax below, legs, and genitalia pale straw-colored. Wing membranes clear, the veins brown. Remain-

der of head and abdomen unpigmented except for dark red-brown marks (also on thorax) distributed as follows: a line over each antennal insertion, the two joined by a pale brown line across front; the two lines above antennae each joined to a band starting posterior to antenna and continuing to abdominal segment 7, widest on abdomen.

Allotype ♀.—Measurements: Total body length 1.67 mm; forewing length 1.73 mm; hindwing length 1.33 mm; hind tibia length 0.73 mm; hind tarsus: T_1 0.200 mm; T_2 0.080 mm.

Morphology.—Gonapophyses (Fig. 49) a pair of rather elongate flaps, narrow at base and directed mesally near base. Subgenital plate (Fig. 48) with a very weakly delineated extended apical region; a more heavily sclerotized area (detectable by staining with acid fuchsin) outlined proximally in dashed lines and extending distally to the apex. A colored ventral interior plate absent.

Color same as in holotype.

Variation.—On one paratype ♀ the red-brown lateral bands do not extend beyond the 4th abdominal segment.

Type locality.—Texas, Palm Grove near Brownsville, holotype ♂, allotype ♀, 8 ♀ paratypes and 6 nymphs, Oct. 1, 1951, beating palms. Other paratypes (not including nymphs)—type locality, 14 ♂, 30 ♀, 26 nymphs, Oct. 2 and 3, 1951, beating dead palm leaves; near Brownsville, 1 ♀, Oct. 4, 1951. All collected by A. B. Gurney.

Types in U. S. National Museum, no. 63241.

It is a pleasure to name this species in honor of L. J. Bottimer, of Kerrville, Tex., a devoted collector and a specialist in the Bruchidae, who assisted the junior author in many ways while at Kerrville and during a week-end trip to Uvalde and Garner State Park.

Family Archipsocidae Pearman

Archipsocus floridanus Mockford

Archipsocus floridanus Mockford, 1953, p. 116.

Palm Grove near Brownsville, Oct. 3, 1951, 2 ♂, 12 macropterous ♀, 9 micropterous ♀, 16 nymphs, from webs on tree, A. B. Gurney.

Archipsocus nomas Gurney

Archipsocus nomas Gurney, 1939, p. 502.

Palm Grove near Brownsville, Oct. 2 and 3, 1951, webs on tree, 2 ♂, 3 macropterous ♀, 8 micropterous ♀, 6 nymphs, A. B. Gurney; Brownsville, Apr. 20, 1953, webs on ebony limb, 32 brachypterous ♀, 5 nymphs (some macropterous).

Group Psocetae Pearman

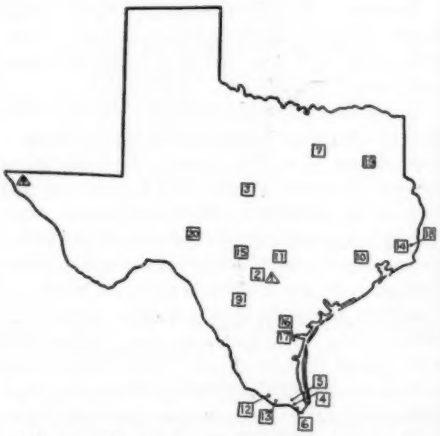
Family Myopsocidae Enderlein

Lichenomima sp.

Brownsville, Feb. 29, 1952, 1 ♀, D. L. Bauer.

Family Psocidae Stephens

Dr. Sommerman is currently preparing a revision of this family for North America and will include distribution records from Texas in her paper. The following species have been recorded from Texas: *Psocus pollutus* Walsh, *P. bisignatus* Banks, *P. campestris* Aaron, *P. persimilis* Banks, *P. submarginatus* Aaron, *P. texanus* Aaron, *Trichadenotecnum unum* Sommerman, *Cerastipsocus venosus* (Burmeister), *Metylophorus purus* (Walsh), and *Blaste quieta* (Hagen).



Map 1.—Outline map of Texas, showing location of localities mentioned. Squares represent definite localities, triangles county records only.

Alphabetical List of Counties in Which Localities Mentioned in This Paper Are Located

Numbers on map correspond to those of the list.

1. Bexar—County record only.
2. Bexar—San Antonio.
3. Brown—Bangs; Brownwood (about 8 miles east of Bangs).

4. Cameron—Brownsville.
5. Cameron—Olmito Resaca.
6. Cameron—Palm grove.
7. Dallas—Dallas.
8. El Paso—County record only.
9. Frio—Dilly (Frio State Park).
10. Harris—Houston.
11. Hayes—San Marcos (Ezel's Cave).
12. Hidalgo—Mission.
13. Hidalgo—Weslaco.
14. Jefferson—Beaumont.
15. Kerr—Kerrville; Kerrville State Park.
16. Nueces—Corpus Christi.
17. Nueces—Corpus Christi State Park.
18. Orange—10 miles west of Orange.
19. Smith—Tyler.
20. Sutton—Sonora (Wyatt Cave).

REFERENCES

AARON, S. FRANK. *Collecting on the Gulf coast of Southern Texas.* Papilio **4:** 159–161. 1884.

———. *On some new Psocidae.* Proc. Acad. Nat. Sci. Philadelphia 1886: 13–18, pl. 1.

ASHMEAD, W. H. *On a new* Psocus. Can. Ent. **11:** 228–229. 1879.

BADONNEL, ANDRÉ. *Psocoptères.* Faune de France **42:** 1–164, figs. 1–375. 1943.

———. *Psocoptères de la Côte d'Ivoire.* Rev. Fr. Ent. **16:** 20–46, figs. 1–61. 1949.

———. *Ordre des Psocoptères:* 1301–1340, figs. 1135–1170, *In* Traité de Zoologie **10,** fasc. 2. Ed. by P. Grassé. Paris, 1951.

———. *Psocoptères de l'Angola.* Compahia Diamantes Angola Pub. Cult. **26:** 1–267, 625 figs., pls. 1–4. 1955.

BAILEY, L. H. *Revision of the palmettoes.* Gentes Herb. **6,** fasc. 7: 367–459, figs. 186–251. 1944.

BAILEY, VERNON. *Biological survey of Texas.* North Amer. Fauna no. 25: 1–222, illus. 1905.

BANKS, NATHAN. *New Neotropical insects.* Bull. Mus. Comp. Zool. **64:** 299–362, pls. 1–7. 1920.

———. *Descriptions of new neuropteroid insects.* Bull. Mus. Comp. Zool. **65:** 421–455, pls. 1–4. 1924.

———. *New neuropteroid insects from the United States.* Psyche **37:** 223–233, 1 pl. 1930.

BLAIR, W. FRANK. *The biotic provinces of Texas.* Texas Journ. Sci. **2:** 93–117, fig. 1 (map). 1950.

BORROR, DONALD J., and DELONG, DWIGHT M. *An introduction to the study of insects:* 1–1030, illus. (Psocoptera, pp. 169–179). New York, 1954.

BROWN, R. W. *Composition of scientific words:* 1–882. Washington, D. C., 1954.

CALVERT, PHILIP P. *Samuel Francis Aaron.* Ent. News **58:** 137–140. 1947.

CHAPMAN, PAUL J. *Corrodentia of the United States of America: I. Suborder Isotecnomera.* Journ. New York Ent. Soc. **38:** 219–290, 319–402, pls. 12–21. 1930.

CLOVER, ELIZADA U. *Vegetational survey of the lower Rio Grande Valley, Texas.* Madrono **4:** 41–66, 77–100, illus. 1937.

COOK, O. F. *Change of vegetation on the south Texas prairies.* U. S. Bur. Plant Indus. Circ. **14:** 1–7. 1908.

DAVIS, ANNA M. T. *A study of Boscaje de la Palma in Cameron County, Texas, and of* Sabal texana. Unpublished thesis for M. S., University of Texas (1942): 111 typed pp., 40 pls. of photographs, maps, etc.

DICE, LEE R. *The biotic provinces of North America:* 1–78, 1 map. Ann Arbor, 1943.

ENDERLEIN, GUNTHER. *Morphologie, Systematik und Biologie der Atropiden und Troctiden.* Results Swed. Exped. Egypt. White Nile, 1901, **18:** 1–58, 11 text-figs, 4 pls. 1905.

———. *Einige notizen zur Kenntnis der Copeognathen Nordamerikas.* Stett. Ent. Zeit. **67:** 317–320. 1906.

———. *Copeognatha, In* Collections Zoologiques du Baron Edm. de Selys Longchamps, fasc. 3, pt. 2: 1–55, 10 text-figs., 5 pls. 1919. (Copies bear the printer's date of 1915, also a printed notation on the inside title page that distribution date was March 1, 1919. The Smithsonian copy is stamped as received Sept. 13, 1919. Listed as 1915 in the 1918 Zool. Record, which, however, was not published until October 1920.)

GALTSOFF, PAUL S., et al. *Gulf of Mexico, its origin, waters, and marine life.* Fish and Wildl. Serv. Fishery Bull. 55: 604 pp., 74 figs. 1954.

GOLDMAN, EDWARD ALPHONSO. *Biological investigations in Mexico.* Smithsonian Misc. Coll. **115:** 1–476, 70 pls. 1951.

GUNTER, GORDON, and HILDEBRAND, H. H. *Destruction of fishes and other organisms of the south Texas coast by the cold wave of January 28-February 3, 1951.* Ecology **32:** 731–736, illus. 1951.

GURNEY, ASHLEY B. *Nomenclatorial notes on Corrodentia, with descriptions of two new species of* Archipsocus. Journ. Washington Acad. Sci. **29:** 501–515, figs. 1–15. 1939.

———. *A synopsis of the psocids of the tribe Psyllipsocini, including the description of an unusual new genus from Arizona.* Ann. Ent. Soc. Amer. **36:** 195–220, 6 pls. 1943.

———. *Distributional and synonymic notes on psocids common to Europe and North America, with remarks on the distribution of Holarctic insects.* Journ. Washington Acad. Sci. **39:** 56–65. 1949.

HAGEN, H. A. *Synopsis of the Neuroptera of North America: With a list of South American species.* Smithsonian Misc. Coll. **4:** 1–347. 1861.

KOLBE, H. *Monographie der deutschen Psociden mit besonderer Berücksichtigung der Fauna Westfalens.* Ber. Westfalischen Provinzial-Vereins für Wissens. Kunst. **8:** 73–142, 4 pls. 1880.

———. *Neue Psociden der paläarktischen Region.* Ent. Nachrichten **8:** 207–212. 1882.

LINNAEUS, C. Systema naturae, ed. 10: 823 pp. Stockholm, 1758.

MOCKFORD, E. L. *Three new species of* Archipsocus *from Florida*. Florida Ent. **36**: 113–124, 30 figs. 1953.

——. *Notes on some eastern North American psocids with descriptions of two new species*. Amer. Midl. Nat. **53**: 436–441, 2 pls. 1955.

PACKARD, A. S., JR. *New or rare American Neuroptera, Thysanura, and Myriapoda*. Proc. Boston Soc. Nat. Hist. **13**: 405–411. 1870.

PEARMAN, J. V. *New species of Psocoptera from warehouses*. Ent. Monthly Mag. **65**: 104–109, figs. 1–3. 1929.

PEARMAN, J. V. *Third note on Psocoptera from warehouses*. Ent. Monthly Mag. **78**: 289–292, figs. 1–3. 1942.

ROESLER, RUDOLF. *Die Gattungen der Copeognathen*. Stett. Ent. Zeit. **105**: 117–166. 1944.

RUSSELL, R. J. *Climates of Texas*. Ann. Assoc. Amer. Geogr. **35** (2): 37–52. 1945.

SELYS-LONGCHAMPS, E. DE. *Notes on two new genera of Psocidae*. Ent. Monthly Mag. **9**: 145–146, 2 figs. 1872.

SMALL, J. K. *The palmetto-palm*, Sabal texana. Journ. New York Bot. Gard. **28**: 132–143. 1927.

SOMMERMAN, KATHRYN M. *A revision of the genus* Lachesilla *north of Mexico*. Ann. Ent. Soc. Amer. **39**: 627–661, 4 pls. 1946.

———. *Two new Nearctic psocids of the genus* Trichadenotecnum *with a nomenclatural note on a third species*. Proc. Ent. Soc. Washington **50**: 165–173, figs. 1–19. 1948.

——. *Two new species of* Rhyopsocus *(Psocoptera) from the U.S.A., with notes on the bionomics of one household species*. Journ. Washington Acad. Sci. **46**: 145–149, figs. 1–17. 1956.

TAYLOR, W. P. *Geographic distribution of Texas wildlife*. Texas Geogr. Mag. **9**(1): 1–12. 1945.

BARRO COLORADO BIRDDOM

On Barro Colorado Island, the Smithsonian Institution's tropical preserve in Gatun Lake, Panama Canal Zone, there is a "bird that roars like a lion." The roar, sometimes mistaken for the call of a howler monkey, is the male courtship song of the turkeylike curassow. The female usually is silent.

Weirdest of the feathered creatures of the preserve is the fruit-eating hawk known as "burja," the witch—a bird about the size of a raven. It has a coal-black back, a white belly, red feet, and a greenish-yellow bill which sometimes is slightly blue at the tip. The name, however, is due less to its weird appearance than to the almost continual "scolding" at other birds or at any intruder into its retreat.

What may appear like fashions in birddom is illustrated by the curious behavior of another Barro Colorado denizen, the motmot, a lovely grayish-green bird with a chestnut-colored head and neck. These have tails that look like tennis rackets. They are fashioned by the birds themselves which pluck off about an inch of the feather vane below the ends of the two outermost feathers. The bird swings this tail from side to side like a pendulum.

A fierce little fighter is the violet-throated hummingbird, one of the most colorful feathered creatures found on the island. This bird, *Anthracothorax violaceicollis*, sometimes builds its solitary nest in the most exposed part of a tree, with no leaf within 25 feet or more. Then it demands dominion over the whole tree and does not hesitate to attack other birds many times its size. It attacks fearlessly, for example, the giant oriole, or oropendula, which is the size of a North American crow. The oriole is described as "helpless as a dirigible before a pursuit plane." When not fighting, the mother hummingbird sits on the nest nearly all the time, protecting eggs and young from sun and rain. The male seldom is seen. There is some reason to believe that his mate drives him away as soon as the eggs are laid. Although generally resentful of the large orioles in the same tree, sometimes it cooperates with them. A species of cowbird has a habit of laying its eggs in the oropendula nests. The hummingbird does not hesitate to drive it away, although its own nest is entirely safe.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

PHILOSOPHICAL SOCIETY

1414TH MEETING, OCTOBER 7, 1955

THEODORE LITOVITZ, of the Catholic University of America, spoke on *Ultrasonics and the liquid state*. By ultrasonics is meant mechanical vibrations at frequencies from 20 kilocycles up to the present practical limit of 500 megacycles per second or more. These vibrations can cause changes of three kinds in the matter through which they pass: a volume change caused by pressure, a temperature change caused by adiabatic compression, and a change in shape caused by shear forces. In some or all of these the strain may lag the stress, with a relaxation time characteristic of the particular mechanism involved. The velocity of propagation and the absorption are both functions of the frequency that differ from those calculated from classical laws. As the frequency increases, the shear viscosity, for example, may "relax out" and the absorption due to it disappear. In shear the stress from the ultrasonic vibration biases the lattice, and the molecules jump to a new position, at a rate measured by the diffusion time. At high frequencies there is not time for them to jump and the lattice appears rigid.

At low frequencies, and in all liquids except the monatomic ones, the effective viscosity is higher than the classical amount. In explanation, a volume viscosity is postulated which relaxes as the frequency rises. For non-associated liquids, a thermal relaxation is postulated, but it does not do for associated liquids with high dipole moments. In them the volume viscosity has the same temperature dependence as does the shear viscosity.

In water the extra energy loss is not caused by thermal relaxation, because it has been shown that in water at 4° (where there is no adiabatic heating on compression because $\partial v/\partial t = 0$) the absorption is the same as at 20°, where $\partial v/\partial t$ is not zero. The phenomenon seems to be a "structural relaxation," i.e., when the water is compressed, flow occurs in the direction of closer packing, and the loss comes directly from the lagging volume change, not from a temperature change. If there is a lag in the flow, there is absorption.

In both shear and volume viscosity in water, bonds are broken with the same activation energy. Hall showed that water is a mixture of two packings: "ice" and "close." Compression upsets the equilibrium between them and one can then calculate the compressional viscosity on this assumption, and the temperature dependence agrees well with calculation.

Comparing dielectric relaxation with ultrasonic, we find there is also relaxation and absorption in dielectrics, but it is traceable here to a rotation as compared to translation under ultrasonic stress. The dielectric relaxation time has the same temperature dependence as the compressional viscosity, hence they have the same activation energy. But the actual times may not be the same. In glycerol, however, the acoustic and dielectric relaxation times are in fact the same, while in nearly all other liquids the rotational jump can take 1,000 times longer than the displacement.

The velocity in fluid is, of course, related to the adiabatic compressibility. The compression of a liquid is in two parts: (1) Change the lattice spacing, (2) change in the arrangement. Liquids are more compressible than solids because their structure can change. At high frequencies, therefore, one might expect a liquid to become solid-like. 25% of the total β (compressibility) in liquids comes from the change in structure, and the velocity increases as the frequency rises above the relaxation time of the structural change.

On cooling arachlor, this viscous liquid behaves more and more like a solid as its viscosity rises, but the temperature dependence is still almost big as a liquid. Such behavior is appropriate to a glass. In a liquid the number of holes decreases with the temperature, which is not true for crystalline solid. Arachlor and glycerol show a low temperature dependence after they become glassy. β_0 approaches β_∞ as T goes down. The liquid thus becomes a solid without crystallization.

Mr. Shapiro gave, as an informal communication, a report on the Cosmic Ray Conference at Guanajuato in Mexico, at which for the first time in many years Soviet members were in attendance.

The tribute was paid at that conference to our past president Mr. Forbush for his extensive and valuable work.

Mr. Potter gave an informal communication calling attention to certain heresies in genetics, to the latest biological theories of Mr. Gamow, and to the "hope that springs eternal in the mechanistic breast." (*Secretary's abstract.*)

1415TH MEETING, OCTOBER 21, 1955

ROBERT J. MAURER, of the University of Illinois, spoke on *Photoeffects and excitons in alkali halides.* The "exciton" is a lonely concept, or particle if you prefer, in solid state physics; a rare and little understood thing that deserves to be more widely used. Consider the excited atom: after 10^{-8} seconds, or eight seconds, or even hours, it may descend to the ground state, but if it meantime suffers a collision it can pass on its energy to whatever it strikes. In a condensed system—a solid—this passing on occurs very rapidly and continues until the energy reaches some impurity, or imperfection, or the surface, where it may produce a photoelectron, or release radiation. In the Bloch approximation the energy levels are reduced to a single system, and an electron moves in the total potential field, but this approximation is defective because it provides no excited states. The concept of excitons does so. In diamond, for example, electrons in the valence band are lifted to the conduction band by absorbing a quantum, and the electron and the hole from whence it came then migrate freely—effectively an infinite distance apart. Now, just at the absorption edge we should have an optical absorption band structure, corresponding to electrons lifted up to the conduction band but not fully away from the neighborhood of the hole from whence they came. The hole and the electron then move together through the solid as a neutral particle, possessing energy. One should thus have "exciton bands," just below the conduction band in energy and just below the absorption edge in frequency.

Of the possible ways to demonstrate this mechanism, only the photoelectric effect and photoconduction are thus far amenable to experiment, and substances that will be suitable are hard to find. In AgCl for example the exciton bands lie so close to the ionization levels that even the thermal energy kT pushes the excitons on up into full ionization.

The speaker discussed Apker and Taft's photoelectric experiments in some detail: experiments with alkali halides containing a goodly number (10^{19}/cc) of F centers, i.e., either extra alkali atoms, or missing halogens whose places are filled by electrons. A pure crystal does not show photo current. The yield curves show a plateau (plotting current against electron volts) from 2 to 5 volts and strong peak at 5.6, which comes from the fundamental absorption spectrum. Apker and Taft suggest that the absorbed quantum becomes an exciton and moves about until it meets an F center from which it expels an electron.

In Maurer's work crystals with known concentrations of F centers were exposed to quanta in the tail of the absorption spectrum and the photoconductive current was measured. A difficult experiment, since the currents are down in the ratio of the mean free path in the gas to the distance apart of the atoms in the solid. One can determine the lifetime of the exciton as a function of the F center concentration, since the *mfp* is inversely proportional to the F center concentration and the velocity of the exciton is about 10^7 cm/sec. Below 10^{15} centers per cc impurities compete too heavily, and the current is small because few excitors are produced and the interfering effects are many. Above 2×10^{17} the currents fall again because the F centers destroy the excitons before they can go very far. The lifetime turns out to be of the order of 10^{-9} seconds.

Curves of current against energy, and against concentration were displayed, and a number of yet little understood points were discussed. These experiments are considered, however, to be a direct approach to the problem of the existence of the exciton, and the results are interpreted in terms of them. (*Secretary's abstract.*)

1416TH MEETING, NOVEMBER 4, 1955

ROBERT JASTROW, of the Naval Research Laboratory, spoke on *The structure of the atomic nucleus.* That the nucleus has a structure has been known for fully 25 years, but only in the last 5–8 years have we accumulated enough facts to develop an acceptable theory of its behavior. We are not yet in the state where our knowledge of the internucleon forces is such that a complete structural theory is merely an exercise in mathematics, but are rapidly approaching the reverse

state, where we should soon be able to calculate the forces from the facts.

A nucleus consists of neutrons and protons, with an excess of neutrons, packed into an approximate sphere at a uniform density of 10^{38} nucleons per cc, or 400,000 tons per cubic millimeter. The average inter-nucleon distance is 2×10^{-13} cm, and attractive forces bind them into a potential well about 40 Mev deep, with kinetic energies up to 30 Mev.

Two different models suggest themselves. First, the classical liquid drop, with long range attraction and short range repulsion, and a mean free path of the order of the "cell-width." The mean spacing is about equal to the range of the repulsive force. Second, the electrostatic action between particles; weak compared to the central force.

Which fits the nucleus? To find out, the nucleus has been probed with beams of particles of various energies, and the scattering laws have been investigated, remembering that the de Broglie wave length for 350 Mev particles is of the same order as the size of the nucleus and that quantum, not classical, laws apply. At lower energies the cross-section increases rapidly, as $1/E$, and the mean free path of the entering particle is much less than r, the nuclear radius. Consequently the nucleus is opaque, and it displays a cross section of $2\pi r^2$. (The 2 comes half from absorption, half from shadow scattering). The approximate expression for the cross-section becomes: $\sigma = f(A, E)$ where R varies as A and as $1/E^{1/2}$. The variation of σ with A and E should therefore be uniform, monotonic, and slow: in a word, "dull". Experimentally, though, there are hills and valleys in a three dimensional plot of sigma against A and E: The most conspicuous example of which is "Mount Barschall", appearing at high energies in the intermediate masses. To account for this we must postulate a transparent nucleus, showing diffraction effects and phase changes in the particle wave-functions as they pass through it. If the phase change is 180° the scattering is a maximum. "Monte Carlo" Calculations, using this postulate, yield sigma-surfaces that agree reasonably well with experiment.

On the other hand, the existence of a shell structure can be demonstrated by showing how the nuclear quadrupole moments vary with A, the atomic weight. Repeated large changes in the sign and magnitude of the nuclear quadrupole moment occur at the so-called "magic numbers": 2, 8, 28, 50, 82, 126. The largest nuclear quadrupole moment known is shown by Lutecium 128, corresponding to an elliptical eccentricity of 25 per cent. One consequence of a quadrupole moment was shown by comparing the scattering of protons from gold with that from tantalum. Gold has zero moment and shows strong diffraction maxima and minima in a plot of scattering against angle. Tantalum has a large moment and shows only small inflections. In tantalum the random orientation of the ellipticity smears out the diffraction structure.

The nucleus remains something of a paradox: having a long mean free path for particles entering it, but acting on them with very strong forces. (*Secretary's abstract.*)

1417TH MEETING, NOVEMBER 18, 1955

WILLARD H. BENNETT, of the Naval Research Laboratory, spoke on *Solar protons and aurorae.* The talk outlined recent results in formulating the theory of aurorae, or "northern lights." Two forms have been observed: the "quiet arc," seen as a general glow, and the other more spectacular form seen as rays and brightly colored draperies. The earliest attempt at a rational theory was Birkeland's in 1896, who postulated that the sun projected particles that were deflected by the earth's magnetic field as they entered it. On this basis Carl Störmer calculated the orbits of the beam. The theory was not generally accepted because it was believed that the charged particles of which the beam was composed would repel each other and not remain concentrated in the narrow beams needed to produce the sharply localized effects. More recently Martyn theorized that the protons and electrons are projected from Sun's surface simultaneously in the form of jets and streams which sweep across the earth's atmosphere. The electrons are deflected while the protons reach the earth. A particle of 1 BEV may penetrate to 19 kilometers from the surface, while a 100 KEV particle may reach only 100 Km. The difference between the northern and the southern auroral zones is accounted for by the fact that the earth's magnetic axis does not pass through the center of the earth. The change in the relative inclination of the axis with the seasons accounts for the seasonal nature of the phenomenon.

A gas tube, called the "Störmertron," has been devised to simulate the aurorae in the laboratory. A stream of electrons from a gun passes through mercury vapor at a very low pressure in a glass envelope. In the center of the tube is a simulated earth, containing a small magnet. The direction of the beam and the orientation of the "earth" are continuously variable, and the luminous beam twists and turns through fantastic convolutions as the initial direction is swung back and forth across the earth. Fluorescent material on the earth shows by bright patches whenever the beam actually strikes it. The phenomena were most strikingly shown by motion pictures of the tube in operation. Sometimes the beams are actually twisted in a tight helix in a captive orbit and produce a bright halo around the earth, which simulates the general glow. The path sometimes takes the form of a series of rose-petal curves striping northern and southern hemispheres alternately. This behavior accounts for aurorae observed in Fairbanks Alaska (for example) followed minutes later by a similar display off South Africa, and still later by one in Norway. In the actual aurorae, the 2½ Mev protons produce electrons of 10 to 15 volts, which luminesce upon returning to the ground state.

In discussion, McNish emphasized the difficulties encountered in formulating an adequate theory and in convincing the skeptics. Answering Mr. Mohler, the speaker confirmed the observation of maximal phenomena at about 9 p.m. local time. (*Secretary's abstract.*)

1418TH MEETING, DECEMBER 2, 1955

MAURICE M. SHAPIRO, of the Naval Research Laboratory, gave a paper on *Megalomorphs*, a term invented by J. R. Oppenheimer to describe the larger cosmic ray fragments known variously as Heavy Mesons, Hyperons, and Heavy Fragments.

The lighter particles found in cosmic rays and produced by the Bevatron were first described and listed, with slides showing their weights, half lives, charges, and relevant genetic relationships. Among them are π^+, π^0, π^-; μ^+, μ^-, and the k mesons that seem to be the source of internucleon forces. There are also the τ, θ, and k mesons with lives of the order of 10^{-8} seconds, which though short, are much too long to be understood on any simple theoretical basis. As an example of the complexity of the phenomena, a complete event was shown on a slide, consisting of five generations of particles forming an "energetic star". The steps in the sequence are: primary particle, a burst of 8 to 10 protons, a tau meson, 3 pi mesons, mu mesons, and finally some common or garden-variety electrons. The pi mesons can produce "neutron stars," and one in three do so.

The speaker then turned to particles heavier than protons or neutrons; the Y, K, and L classes of Hyperons. Given as examples of these were Λ^0, Σ^+, Σ^-, and Ξ particles. These are all "excited nucleons", and the emission of pi mesons by them is quite analogous to the emission of light by excited atoms. As a specific example, the Λ^0 particle weighs 2181 electron masses, has a mean life of 3.7×10^{-10} secs, and breaks up into a proton and a pi minus meson with a reaction energy, Q, of 36.9 Mev. The Σ and Ξ are similar.

The Hyperfragment is another class of particle with various weights and energies. A tritium fragment, for example, in the right state of excitation will break up into a ${}_2He^3$ atom and a pi minus meson. In other words, the fragment had part of its structure replaced by a hyperon. These reactions have definite components, products, reaction energies and half lives.

The beginning of an understanding of this maze of reactions involving these transient entities is coming about through the introduction of a sort of quantum number with unique selection rules. This number is called the "strangeness", and is as characteristic of any given particle—at least as presently conceived—as is its charge or half life. "Strangeness" must be conserved in a "strong interaction"; spontaneous decay is a "weak reaction", and the decay of many of these particles is much slower than would be expected because there is a change in "strangeness" between components and products.

After a discussion, in which Messrs Wood, Page, Maxwell, Tuckerman, Mohler and others took part, the speaker was asked to report on the recent discovery of the "anti-proton" at Berkley, where he had been visiting. (*Secretary's Abstract.*)

Facts are the body of science, and the idea of those facts is its spirit.—S. BROWN.

VOL 1 NO 1 1959
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